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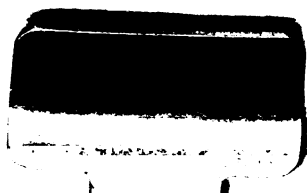
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Regulation and Repair of Piano and Player Mechanism

together with

Tuning as Science and Art

ILLUSTRATED

By

WILLIAM BRAID WHITE

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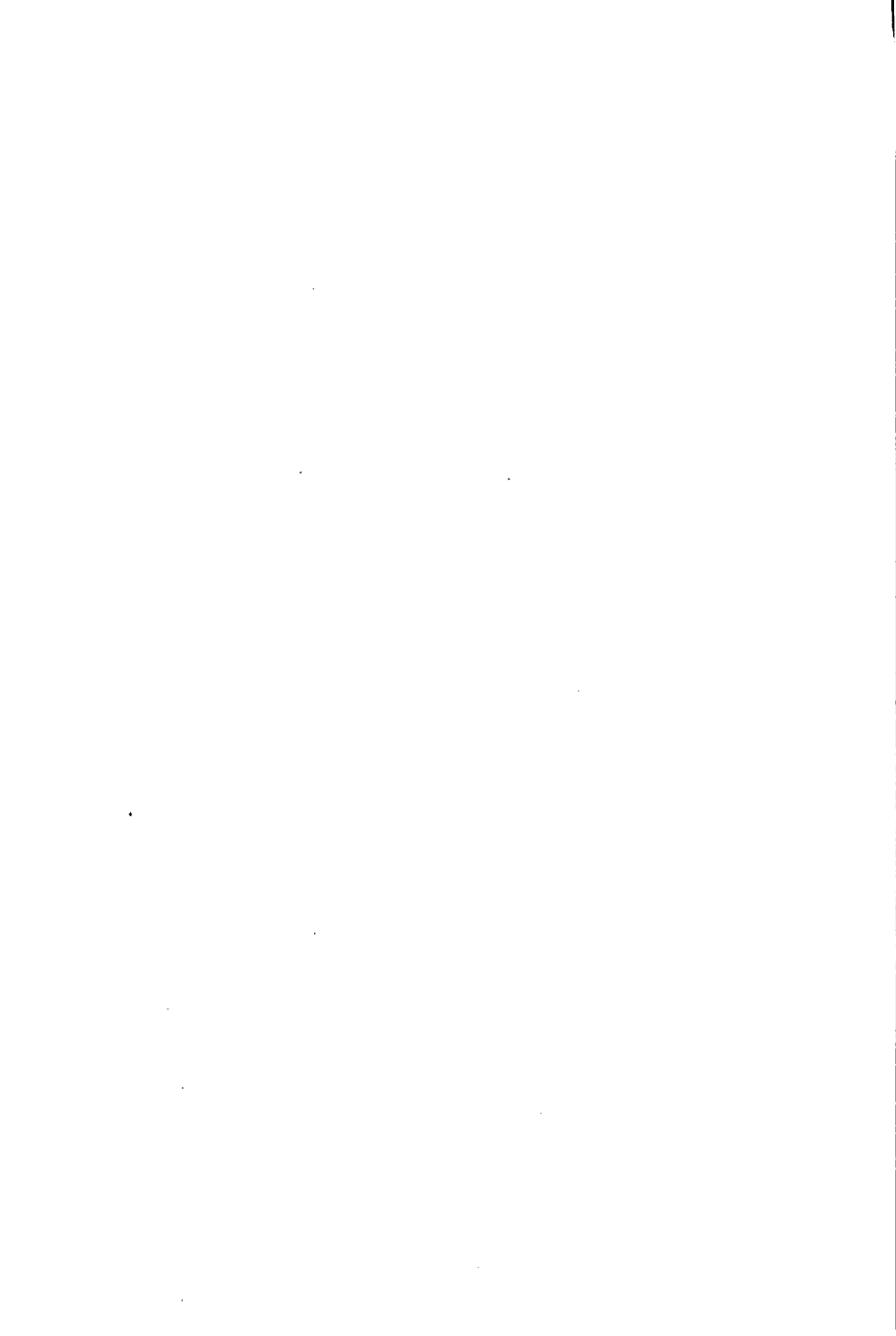
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SOME INTRODUCTORY REMARKS.

The development of the player piano put forth under various names coined by manufacturers has been little less than marvelous.

While devices of one kind and another for the automatic mechanical performance of music have existed for a long period, yet the real, the practical advance has been made within the past few years, and to-day it is universally admitted that the player piano is not only a powerful factor in piano selling, but a great educational factor in the development of a love for music. It is stimulating a love for music in thousands of homes where formerly there were idle pianos.

The growth of the industry has been so extraordinary that there has been a dearth of player experts who are capable of solving the ordinary problems of adjustment, regulation and repair which would come quite naturally to every dealer. There was no source from which specific in-

formation could be obtained outside the factories, and it is obvious that but few could visit the various plants for the sole purpose of acquiring information.

Recognizing this void, the publisher put forth, some two years ago, a work entitled "A Technical Treatise on Piano Player Mechanism." Inasmuch as there was not at hand available data from which information could be gleaned, it will be realized at once that, in the preparation of this book, an entirely new field was explored, and it was intended that this book should be a useful aid, not merely to repairers and tuners, but to dealers and salesmen as well. In its preparation it was necessary to minutely examine the principal player systems, and, as a result of study, research and technical knowledge, a volume which constituted a valuable treatise on piano player mechanism was put forth.

The publisher at that time remarked that, inasmuch as the industry was in an evolutionistic state, it was obvious that many changes would occur from time to time in the mechanism of piano players, and that, in order to keep pace with the changing conditions, it would be necessary to issue a supplementary volume at some subsequent date.

While the essentials of piano playing mechanism have remained unchanged, it is deemed necessary to issue a work which would deal more exhaustively with the regulation and repair side of the business.

The pneumatic player is the standard and popular type, and as we view it its supremacy will be maintained, and it is therefore the pneumatic system with which this volume deals.

The necessary peculiarities of player construction give rise to certain problems, and it is the aim of this publication to simplify those problems for the tuner and repairer who is operating at a distance from the factory.

Hence REGULATION AND REPAIR OF PIANO AND PLAYER MECHANISM will, we believe, fill an important position in the technical world.

Combined with this work is a volume entitled TUNING AS SCIENCE AND ART, and it is certain that the information contained in its pages will be found to be interesting and instructive to the tuner and repairer.

Taken as a whole, it is believed that the present volume will form a useful addition to the former technical works put forth by the publisher under the following titles:

“The Piano, or Tuner’s Guide,” “Theory and Practice of Piano Forte Building,” “A Technical Treatise on Piano Player Mechanism,” and it may be remarked that all of these books have received the endorsement of trade and technical experts on both sides of the Atlantic.

It is, therefore, with added confidence that the publisher presents the next of the series, with the belief that it will fill a useful mission in the technical literature of our times.

EDWARD LYMAN BILL,

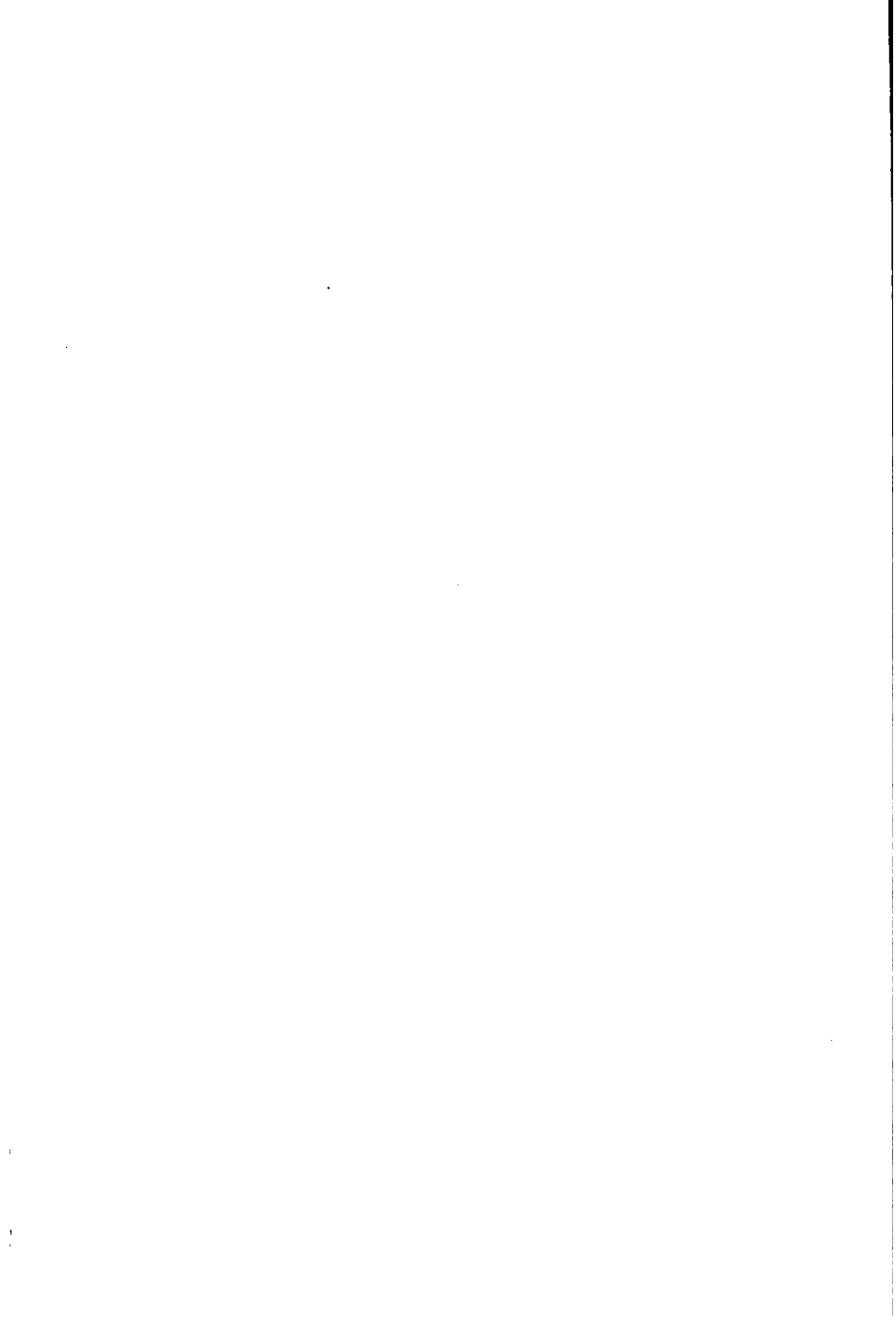
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**REGULATION AND REPAIR
OF
PIANO AND PLAYER
MECHANISM**



CHAPTER I.

ON PIANO-PLAYING MECHANISM; ITS PRINCIPLES, REGULATION AND REPAIR.

No matter how the piano player may strike the musician, the music student or any other expert, to the tuner its most interesting feature lies in the fact that it is being taken up with avidity by the general public, and that the proportion of pianos to player-pianos each year grows steadily smaller.

As a direct consequence of this fact it has become necessary for tuners to acquire an understanding of the player mechanism as well as of the various parts of the piano itself. For the up-to-date practitioner never knows in these days when he may be called upon to regulate or repair a player-piano in the regular course of his day's work. If he is to keep his practice he must be able to do anything with the player mechanism that he may properly be called upon to do; anything, in short, which would not require the equipment of a repair-shop or factory.

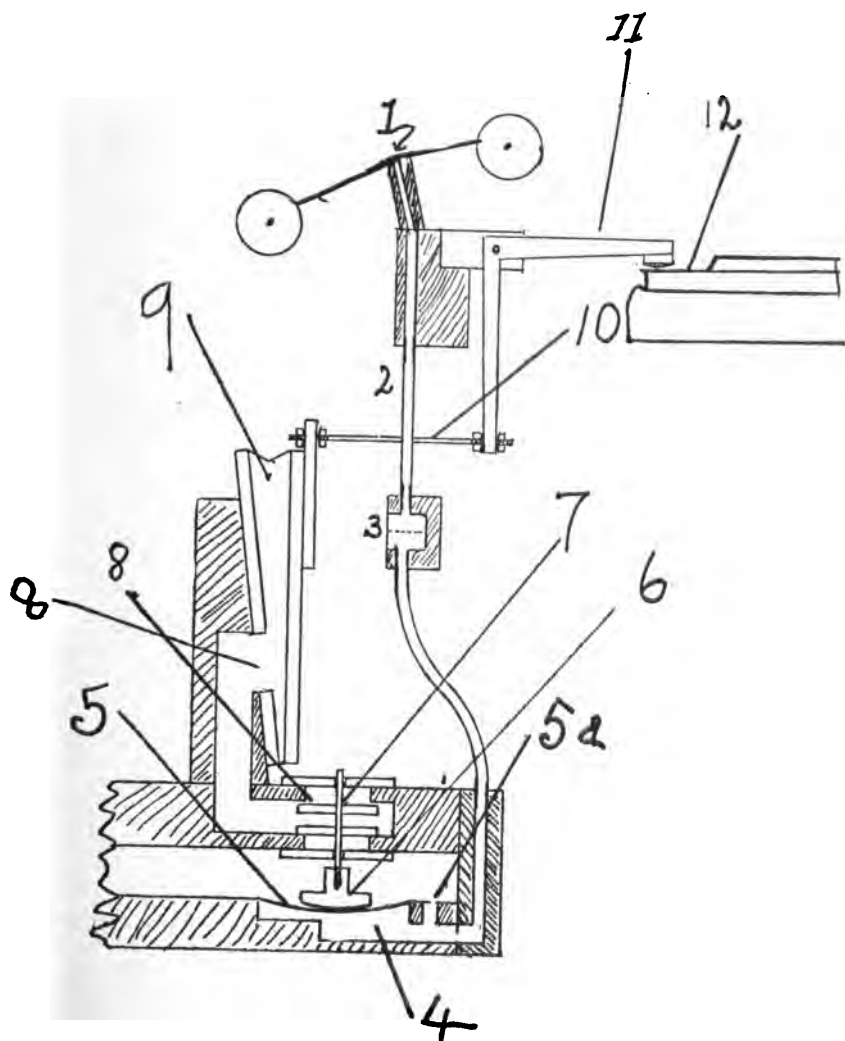
Now it is obvious that the tuner must, there-

fore, be possessed of enough fundamental knowledge to approach the subject intelligently. This fundamental knowledge is not so difficult to acquire, and the present chapter contains enough information to enable any intelligent tuner to understand how a player works, how it is made, and what the usual maladies are which beset it.

Let us begin at the beginning. Consider the drawing attached. It shows the valve and pneumatic action of a simple but efficient form of outside or cabinet piano-player. The figures have the following references:

FIG. 1.

- 1 Trackerboard.
- 2 Tracker tube.
- 3 Tracker tube joint.
- 4 Pouch.
- 5 Exhaust chamber.
- 5a Bleed hole.
- 6 Valve button.
- 7 Valve stem and disks, in exhaust chamber.
- 8 Exhaust-inflate chamber into pneumatic.
- 9 Pneumatic.
- 10 Connection to striking finger.
- 11 Striking finger.
- 12 Piano key.



Now let us see how all this apparatus works. Begin by understanding that this drawing shows the player action at rest. The exhaust chamber, 5, is kept exhausted of air by the action of the bellows (not shown) and the chamber under the pouch, 4, is also exhausted through the bleed hole, 4a, since the trackerboard, 1, is closed by the roll of paper. Hence the valve will stay on its seat, the button, 6, resting just above the pouch, 4, which is drawn down by the suction, which likewise holds the valve disks firmly down, keeping the exhaust from entering the pneumatic and letting the air in through the chamber, 8.

Now, when a hole appears in the perforated roll and registers with a hole in the trackerboard, at once the state of vacuum which has existed down along the tracker tube into the chamber under the pouch is destroyed, as a puff of air at once rushes down the tube. This air forces upwards the pouch, 4, above which is a state of vacuum, and which, therefore, responds instantly to the force urging it below. The valve in consequence rises with the pouch, and remains up as long as there is air underneath it; that is, as long as the trackerboard is still open.

When the valve rises its upper disk shuts off the

air passage into the pneumatic through the inflate-deflate chamber, from which air has been passing into the chamber through the space left by the top disk. This disk has now risen and shut off the air. At the same time the other disk has also risen and has opened a passage or communication with the exhaust chamber, 5, from which the bellows are drawing air continually. Hence the air is drawn out of the pneumatic, through the inflate-deflate chamber, and the former closes, bringing down the finger on the piano key.

All these operations are practically instantaneous, as is proved by the fact that a trill can be executed by the player much more rapidly than the most practiced virtuoso can attempt with the human finger.

When the trackerboard again closes, the rush of air down the tracker tube is stopped, the remaining air in the tube is drawn out through the bleed hole into the exhaust chamber, the vacuum under the pouch is resumed, the valve falls and the air passage is opened again into the pneumatic, which opens, lifting the finger from the piano key.

Precisely the same idea is worked in the interior player action, which is used in the player-pianos,

**KEY TO FIG. 2. DOUBLE-VALVE PLAYER ACTION,
CABINET PLAYER.**

- 1 Tracker tube.
- 2 Tracker duct.
- 2a Bleed hole.
- 3 Primary pouch.
- 4 Primary bottom disk.
- 5 Primary stem.
- 6 Primary top button.
- 7 Air channel to secondary valve.
- 8 Secondary pouch.
- 9 Secondary bottom disk.
- 10 Secondary middle disk.
- 11 Secondary stem.
- 12 Secondary top disk.
- 13 Air and exhaust channel to pneumatic.
- 14 Pneumatic.
- 15 Finger connection fastening.
- 16 Finger connection.
- 17 Striking finger.

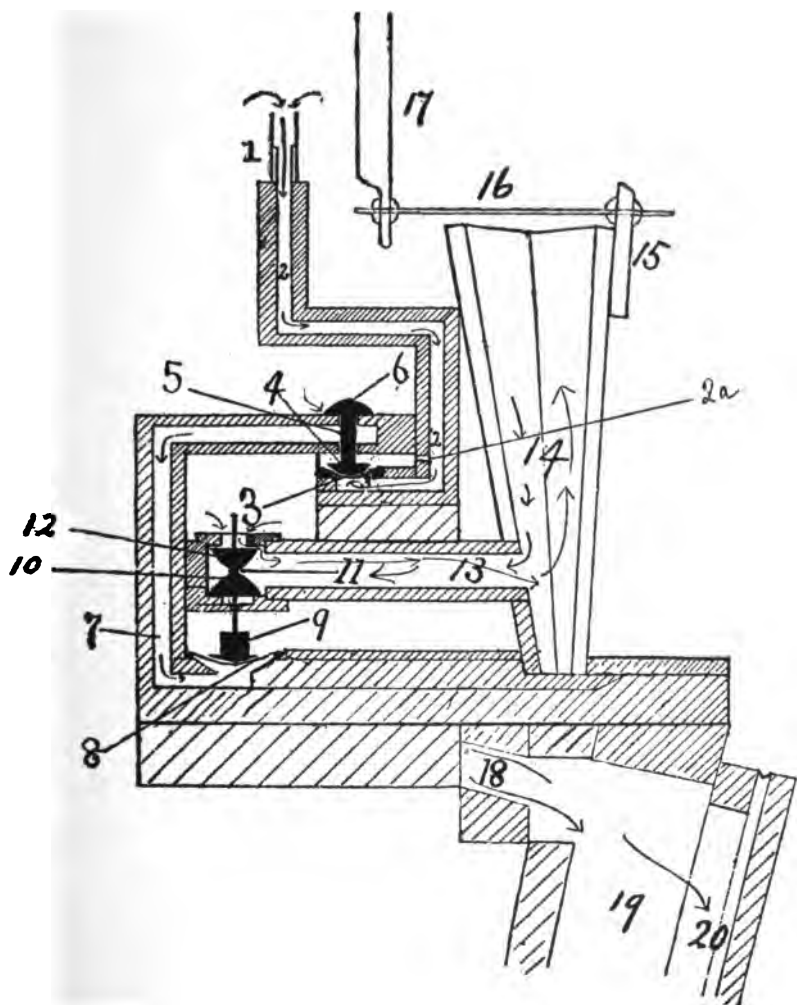


FIG. 2.

the only difference being in the connection of the pneumatic with the piano action.

THE DOUBLE-VALVE SYSTEM.

Although we have here illustrated, for the sake of simplicity, a single-valve system, many players are built nowadays with the double-valve system. That is to say, the first valve rises direct from the force of air rushing down the tracker tube, as shown above. Instead of leading direct to the pneumatic, however, this first or primary valve opens an air passage, which lets air in under the pouch of a secondary valve. The latter rises and opens the pneumatic to the force of the exhaust.

Appended is a drawing which shows how the second valve works.

THE PLAYER MOTOR.

The attached drawing shows the method of rolling the paper over the trackerboard by means of a pneumatic engine or motor. The device consists of three, four or five small bellows, each of which is provided with one fixed wall and one movable wall. Each fixed wall has two ports in it, one connected with the exhaust bellows and one with the open air. A slide valve slides over these two

ports, covering both of them at one part of its stroke, and opening the air port at the other end of the stroke. When both are covered, the air is drawn from the pneumatic through the air port along the passage formed by the cover of the slide valve, and out through the exhaust port. Thus the bellows are alternately inflated and deflated, and the reciprocal motion of the walls is transferred to a crankshaft, which operates on the spools through suitable gears.

THE PLAYER-PIANO ACTION.

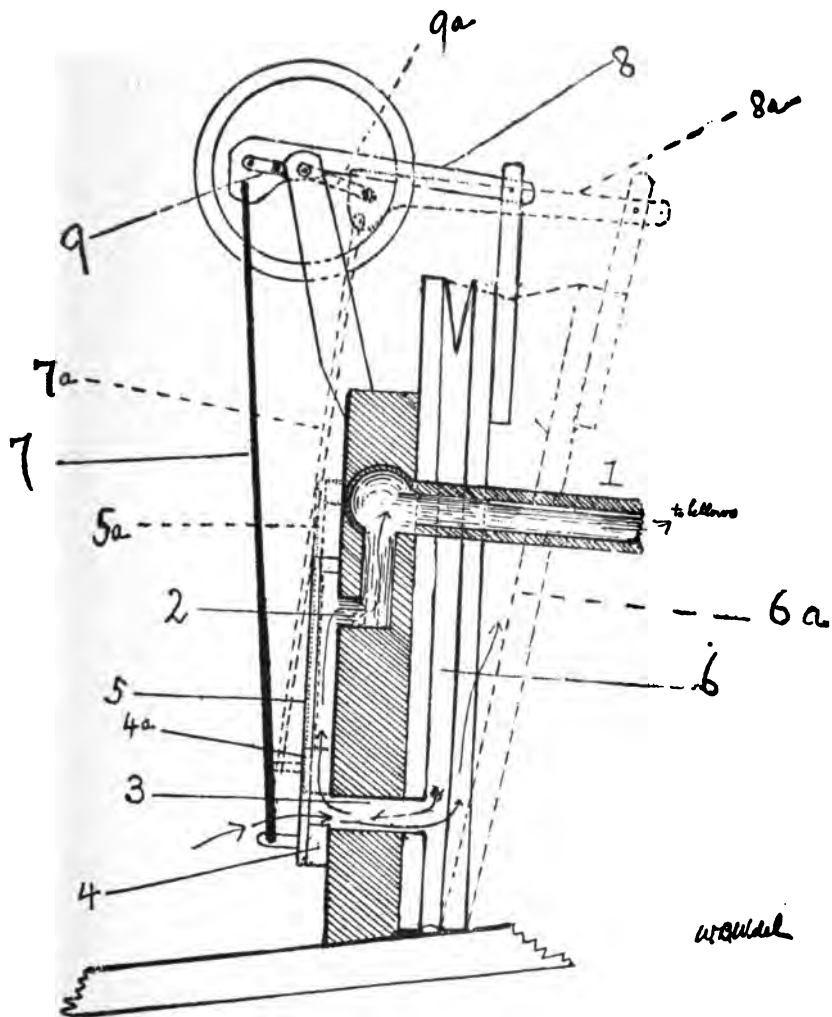
The attached drawing will show quickly how the player-action is attached to the piano in ordinary practice. Any one who has read intelligently the foregoing can understand what is meant throughout.

THE BELLOWS.

The exhausting of air from the action box of the player mechanism is performed by means of a set of bellows operated by the feet. Two foot-pedals are used, each working one exhauster. These exhausters are of large area and must be built very strongly and covered with heavy rubber

KEY TO FIG. 3. PNEUMATIC PLAYER MOTOR.

- 1 Exhaust tube.
- 2 Exhaust port.
- 3 Air port into pneumatic.
- 4 Slide valve showing position with pneumatic closed.
- 4a Slide valve showing position with pneumatic open.
- 5 Slide valve cover; pneumatic closed.
- 5a Slide valve cover; pneumatic open.
- 6 Pneumatic closed.
- 6a Pneumatic open.
- 7 Valve connecting rod; pneumatic closed.
- 7a Valve connecting rod; pneumatic open.
- 8 Crankshaft connecting rod; pneumatic closed.
- 8a Crankshaft connecting rod; pneumatic open.
- 9 Crankshaft.
- 9a Crankshaft.



KEY TO SECTIONAL ILLUSTRATION OF PLAYER-PIANO
(INTERIOR) ACTION.

FIG. 4.

- 1 Pedal.
- 2 Pedal connection.
- 3 Exhauster (one only shown).
- 4 Reservoir; high tension (low-tension reservoir not shown).
- 5 Exhaust trunk.
- 6 Exhaust tube to motor.
- 7 Air space above primary valves.
- 8 Secondary valves.
- 9 Striking pneumatic.
- 10 Connection from pneumatic to action of piano.
- 11 Piano action.
- 12 Pneumatic motor.
- 13 Trackerboard.



FIG. 4.

and canvas cloth in double thickness. Two 7-lb. springs are used to each to keep them pressed together and push them back promptly when they are opened by the pressure of the feet on the pedals.

But the operation of drawing air from the action box would be very unsatisfactorily performed if these exhausters alone were depended upon. Some device must be used to steady the power. Borrowing from the organ, the player-action is fitted with a set of reservoir bellows, which are placed on the side of the main exhaust passage remote from the feeders and which are always two in number. One of these is of relatively large size and is kept extended by two comparatively light springs. This is called the low-tension reservoir. The other is smaller in area, and is extended by more powerful springs. This is called the high-tension reservoir. The function of these is to keep steady the suction power. They operate as follows: When air is drawn from the action box by the exhausters the reservoirs also are affected by the suction and tend to collapse. But the springs in them at once begin to force them open, and so when the power of the spring is greater than that of the foot-pedal pressure, the

reservoirs open more quickly, and as they do so they in turn tend to draw air from the action above them. So, while the exhausters work alternately, the reservoirs work all the time. Hence the power is kept steady. The low-tension reservoir will entirely collapse under very heavy foot-pumping, while the high tension will always stay open more or less. Hence in all conditions the power is kept steady and there is no loss between foot-strokes.

THE TEMPO LEVER.

Every player, whether cabinet or interior, is provided with a lever for regulating the speed of the motor. This lever is connected with a sliding gate, which can be moved back and forth, uncovering more or less a passageway in the exhaust trunk between the bellows and the suction tube which leads to the motor. When the gate is wide open the suction is at its greatest power and the motor moves at full speed. When the gate is more or less closed the suction is proportionately diminished, and the motor moves more slowly, in the same ratio.

In the best players also it is usual to have a little bellows, called a tension governor, the object

of which is to intercept the flow of suction to the motor and cause it to pass through this little bellows, which is kept open by a spring, and tends to overcome any unsteadiness that might be caused in the motor speed through careless pumping. This little governor is always near to the tempo gate.

THE REWIND LEVER.

This lever has a double function. It changes the gear of the motor and throws the music-roll clutch into mesh with the former, thus rewinding the music. Also it slides a gate over the entrance to the tube, which conveys suction to the action box from the bellows, so that the action is cut off and the player cannot sound while the music is being rewound.

THE SUSTAINING PEDAL LEVER.

In the cabinet player this lever is connected with a presser-foot, which communicates with the loud pedal of the piano. In the player-piano this lever acts directly on the damper rod of the piano. Some instruments have a pneumatic button for this office. In this case, depression of the button admits air under a valve and this causes a pneumatic to collapse, which pushes up the pedal rod.

THE SOFT OR ACCENT LEVER.

Every player mechanism has such a lever as this, or a pneumatic button to take its place. Its object is much the same as that of the tempo lever, in a mechanical sense, since it moves a gate back and forth in front of the suction passage to the action, thus admitting, according to the position of the lever, more or less suction power to the action, and causing a more or less powerful collapse of the striking pneumatics. Usually there is a little governing bellows in connection with the accent lever, and practice varies greatly in this respect.

There are many other varieties of control apparatus in players of various makes, but the foregoing are the basic mechanisms and all others are founded upon them.

REGULATION AND REPAIR OF THE EXTERIOR PLAYER.

To take the exterior or cabinet player first is proper in such a chapter as this, since many things may be said concerning it that at the same time are fully applicable to the interior action. The exterior players, though no longer as popular as they originally were, are nevertheless to be found all over the country. Many of them are old and

crude, early specimens of an undeveloped state of the art. The author has had occasion to repair and regulate player-actions not less than nine or ten years old; pathetic survivals of weary struggles with the then almost insuperable difficulties of valve action and control.

One of the peculiarities of these old exterior players, which will at once be apparent to the observer, is that they exhibit most clearly the touching faith of their inventors and manufacturers in their absolute invulnerability against the inroads of time or the wear and tear of daily use. At least one is compelled to such a belief, since one finds that the makers of these instruments built them so that their lack of general accessibility was astoundingly complete. In many old players the rewind valve, motor gate box, expression box and other vital parts are placed behind the exhaust trunk in such a position that bellows, reservoir, trunk and valve board must be slowly and patiently extracted before they can be reached. Some two years ago the present writer was called to repair an old player. It had stood for about five years in the clubrooms of an Elks' lodge, and the merry Brothers of the B. P. O. E. had practiced playing it with an assiduity

worthy of even a better cause. According to the voluntary testimony of neighbors, twelve hours per diem represented the usual work of this long-suffering instrument. In fact, there was general rejoicing when it broke down, while muttered imprecations might have been heard when it was known that the instrument was to be repaired and made capable again of doing an honest day's work.

However, to return to our muttons. The instrument, first of all, refused to rewind. Next the action was not cut off when the rewind lever was thrown over. Then the bellows springs were broken and had been replaced with a pair of coiled springs taken from two door-closing devices. The exhaust tension was, therefore, somewhat light (!). The valve action was sluggish and slow, and some pneumatics refused to work. The instrument represented an excellent example of a player of the old type that had been overworked until it naturally lay down and quit, and a description of the methods adopted in repairing it will indicate, even more clearly than if stated formally, the general method of procedure in such cases.

The first step was to remove the outer casing,

or so much of it as would come off. The action was tightly built into the case and the only things that could be removed were the panels in the front and back. Then the door springs were tenderly removed from the exhaust bellows and the back exhaust trunkboard containing them was taken off. This part was then well cleaned out with a jet of air. The inner board of the exhaust trunk was then also taken off and the gate box of the rewind mechanism gotten at. Before this had been done, however, the primary and secondary valves and primary bleed holes were exposed and carefully cleaned of dust. A piece of piano wire was used to search out the small spaces around the valve stems and bleed holes and thus to clean them out. Then the tracker tubes were detached one by one and the dust blown from them. Then the gate box for the rewind was examined and found to be suffering from a break in the connecting wire, located just outside the box. This was spliced carefully, with due attention to maintenance of the original length. The gate box itself was also examined, and as the valve did not work quite square on the slot, it was squared off with a plane and some fine sandpaper. The other gate boxes were then also examined and regulated in

a similar manner, special attention being directed to the valves, noting whether they worked square on the slots and entirely covered the latter when closed. The exhaust trunk was then carefully replaced, the screws tightened in and the bellows replaced. New springs were put in place and the valve and exhaust actions were then pronounced correct.

The motor was now overhauled. The exhaust and air ports on each unit were well blown out, the slides examined, squared off and made to work easily and tightly. The bellows were examined, and two small punctures in the corners of one of them patched and reinforced. The gear chains and gearing were examined, cleaned, lubricated and carefully timed. (This player is gauged, when new, to run seven feet in six seconds with the tempo level at mark 70. On old machines this speed cannot always be maintained, although it is usually possible to strengthen the springs of the reservoir or tension governor, which will have the desired effect.)

The expression, tempo and rewind levers were next examined, lost motion taken up, and recoil springs strengthened where necessary. Then the machine was tested and found to be in good con-

dition, with the exception of a little weakness in exhaust power. It was then discovered that the reservoir spring was hardly strong enough and that there was a small leak in the corner of the reservoir bellows. So the reservoir came off again, a new and heavier spring was put in, and the leak cemented up. Then all was well and the present writer departed, bearing the good will of the Elks, and possibly the ill will of some of their neighbors.

This somewhat frivolous record of an actual experience indicates the line to be taken in the repairing of a cabinet player. Remember that the first thing to be expected is that the exhaust trunk, reservoir and pumpers will not be quite tight, and the next thing is that the tracker ducts, primaries, secondaries and bleeds will be more or less choked up with dust. Then the motor, if of the pneumatic type, will very likely suffer from general debility in the bellows, as the wear and tear on these are very great. Likewise the motor valve slides will often stick through warping, dampness, or other causes. Then, again, the motor exhaust tube from the main exhaust trunk is likely to leak at the connection with the motor. The same consideration applies to the action exhaust

connection when this is made through an external tube. The motor must be considered with careful reference to its peculiar construction. No oil should be placed on the crankshaft or anywhere else where wood is to be found, but the sprocket chains, gear wheels and pinions may be oiled after they have been carefully cleaned of all gummy and sticky sediment from old oil.

When a pneumatic ciphers—that is to say, when it speaks on a covered trackerboard as soon as the exhaust begins to operate, and before its tracker hole is uncovered—there is a leak somewhere in the tracker tube, or else under the primary valve. Look for the first at once, and you will probably find that the rubber is worn away somewhere.

When a pneumatic apparently does not act, first look to see whether the key digital is properly placed above the key. If not, adjust the latter by the connecting wires from the pneumatic. If, however, it is seen on examination that the pneumatic does not collapse when it should, note whether there is a leak in it. If it is tight, listen for a hissing noise. If the noise is observed to come from near to the pneumatic, the trouble is probably in the secondary valve. If the player is

modern, the primary buttons can probably be easily uncovered by taking off the channel that protects them. As this channel is open to the air, anyway, taking it off will not affect the operation of the player. Now, if the primary valve is seen to act properly, the trouble is in the secondary valve, of which the stem may be bent, or the valve badly seated. If the primary is seen to refuse to act, search for the trouble there first by uncovering the primary and examining it for dirt, warping or refusal of the valve to seat.

When a pneumatic does not repeat well, see whether the primary bleed is choked up, and, if so, clean it by running a fine piece of piano wire or a fifty-six gauge drill through it.

If the bad repetition occurs only on very gentle exhaust caused by light pumping for pianissimo effects, as in playing a soft trill at high speed, then the bleed is possibly enlarged too much. If so, glue a little piece of cardboard over it, entirely covering it, and then pierce a hole of the proper size through the cardboard. A leaky pneumatic, even if it be capable of acting on high exhaust, may often fail to repeat on low exhaust. Most players have the pneumatics glued on to the board, so that they may be easily removed by taking a

knife and running it around and under the edges. They must be carefully replaced in exactly the original position, which should have been marked before removal.

Dust in the tracker ducts will also spoil the repeating qualities of the action, and may be removed by careful cleaning of the tubes with a hand bellows.

It sometimes occurs that the leather diaphragms of the valves are unduly contracted or expanded through peculiar atmospheric conditions. In the one case the valve stems will be lifted too high and the valves raised from their seats, while in the other case they will not raise far enough. In the first case the player will not start easily, and in the other there will be a noticeable lack of dynamic power.

When either primary or secondary valves have been removed they must be resealed with the greatest care. The secondary valve should have a lift of 5-64ths of an inch.

In attempting to regulate the expression devices of a player, let the operator first consider carefully what their functions are. The motor governor, for instance, can be adjusted to speed up the motor and the expression governor so as to

give a harder touch, simply by increasing the resistance of their spring tension. When there are no special governors, the springs of the reservoirs can be strengthened. The gate valves also must be considered, as any failure on their part to close their slots will cause trouble. For instance, if the action cut-off valve in connection with the rewind lever does not completely close its slot, the action will speak on rewinding. The same thing must be considered with reference to the tempo gate box. If this does not close the slot completely when at the shut position the motor will not entirely cease running. Again, if the slot is blocked or clogged up in any way it will affect the steadiness of acceleration or retardation of the motor. Of course, faults in the motor itself are even more likely to be responsible for improper playing. A leak under the rewind gate valve in the tempo box, which is opened when the action is cut off, might also cause the motor to continue moving after the tempo lever is thrown to the "off" position. Some players, however, have no such gate valve, but require that the tempo lever be opened when the action is cut off, the rewind lever performing only the latter function, in addition to changing the gear.

If the choker lever that operates the expression gate box is thrown over to extreme choking position and the regulating bellows simultaneously collapses, the player should refuse to speak. The same test can be made on a divided action, each side remaining silent when its valve and corresponding bellows are tested as described.

The valve and pneumatic operation of automatic accenting devices is similar to that of the regular pneumatic action, and they must be considered with reference to these facts. It should always be remembered that the marginal perforations through which these devices operate are very small, and perfect tracking is, therefore, necessary if they are to give satisfactory service. Many troubles in this mechanism are found to be due merely to improper tracking, owing to swelling or shrinking of the music-roll or other similar reasons. Players fitted with these devices generally have adjustable trackerboards, so that these faults can be at once remedied, even when playing.

Lastly, no exterior player should ever be left as finished until the repairer is sure that it has been properly adjusted to the piano, with the digitals about 1-32d of an inch above the keys and the black key digitals having the middle of

their contact pads just over the end of the black keys.

THE INTERIOR PLAYER.

- The details of regulation and repair of the interior player are naturally of much the same nature as the matters above discussed in reference to the exterior, but there are certain important differences. For instance, most interior players are so arranged that the whole valve box must be removed to make a repair to one valve or pneumatic, and then no test can be made until the player is replaced. So that there are sufficient points of difference to compel careful study of this type.

REGULATION OF THE PLAYER-ACTION WITH THE PIANO.

One of the most important of these points has reference to the connections between the pneumatic action and the piano-action. There are many different ways of effecting this union, and manufacturers have adopted a great variety of devices. Some pneumatic actions strike on tongues extended from the front of the abstracts; others from underneath the wippen. Some strike upwards from under the keybed at the back of the

abstracts, connecting with backwardly extending tongues; others pull down on the fronts of the keys by tape connections extending through the keybed. Some operate a rocking shaft, which, in turn, actuates the abstracts of the action by means of pitman rods extending from under the keybeds; others strike on top of the keys just back of the ivories.

It, therefore, is necessary for the repairer to make a careful study of the particular method adopted in every player that comes under his notice. His own common sense will generally enable him to judge how closely the player-action should and can be regulated to the piano. This is a most important but quite simple matter.

REPAIRING THE INTERIOR PLAYER.

In cases where the action is below the keybed and the tracker tubes are brought down through the former between the keys, look out for the latter sticking on the brass connecting tubes. If the key swells up it is likely to do this. See that the trackerboard is fastened securely to the plate or pin block of the piano, for otherwise it will rattle. Look at the motor, and use the same pre-

cautions with regard to it that have been recommended for the exterior player.

There is little to add in considering the repairing of interior valve systems to what has already been said on the subject with regard to the cabinet instruments. All interior players now have easily accessible primary and secondary valve boards, and the tracker tubes also can easily be displaced or replaced during the process of cleaning. Even where the pneumatic action is below the keyed it is now customary to carry the tracker tubes in two or three groups, at the side or between the sections of the keyframe, so that they do not have to pass between the keys.

It is customary also to provide the keyboard with a lock which holds the keys away from the piano-action when the instrument is pneumatically played. Of course, this cannot be done on players where the pneumatic action pulls down on the front of the key by a tape connection or other similar means. Nevertheless, this is a feature which has a place in this chapter, since it permits a closer regulation of the pneumatic action to the piano and consequently a cleaner touch.

When rattles or buzzings are noticed in an interior player and the trouble cannot be traced to

the piano-action or other parts, the motor of the player should first be examined. If there is nothing loose there, see whether the brackets which hold the motor and tracker frame steady have worked loose and are rattling on the piano plate. If this is all right, see whether the pumper pedals are tight, also whether the screws that hold the pneumatic action in place, as well as those which secure the bellows set, require tightening. Lastly, observe whether any of the moving parts of the pneumatic action are touching the resonant portions of the piano at any point.

It is necessary to remove the pneumatic action in order to get out the piano-action when the former is above the keybed. When it is below the tracker frame must usually come out, anyway. When one desires to put on a new string in the middle or bass sections of the piano the bellows set and pneumatic action must come out. In my "Piano-player mechanism," which considers peculiarities of various leading makes of player, the methods used for taking out these parts have been fully explained.

Otherwise the statements made in the earlier part of this chapter will be found generally applicable to the repairing of interior and exterior play-

ers alike. Experience, study, practice and native skill will supply any assistance that cannot be given in printed directions.

In concluding this survey of regulating and repair practice, it is well to remind the reader that some players, both exterior and interior, are provided with spring motors. These devices are usually of a simple clockwork type, geared to the trackerboard in the ordinary manner. Troubles in connection with these motors are little likely to occur and when they do may usually be attributed to dirt getting into the bearings, which need to be regularly and thoroughly cleansed. The pedal-driven spring motor, which is kept wound by the movement of levers actuated by the pumper pedals, is hardly likely to be overwound, but it might be possible to do this with a handle-wound motor. In such a case the mainspring must be removed and disentangled.

GENERAL HINTS TO THE REPAIRER.

Always carry a tester roll with you. It is best, in fact, to have three. One for 58-note, one for 65-note and one for 88-note players.

Always begin your work by running the tester roll over the trackerboard. In this way you can

at once detect any defects in the speech of the pneumatics and isolate them.

Motors should run at the following speeds:

- 2 feet per minute when tempo lever is at 20 or Largo.
- 4 feet per minute when tempo lever is at 40 or Adagio.
- 6 feet per minute when tempo lever is at 60 or Andante.
- 8 feet per minute when tempo lever is at 80 or Moderato.
- 10 feet per minute when tempo lever is at 100 or Allegro.
- 12 feet per minute when tempo lever is at 120 or Presto.

The timing can be done by marking out 12 feet on the tester roll and using this.

When attempting to glue pneumatics or bellows always use hot glue and warm the edges of the wood where the glue is to set.

Always carefully iron down the edges where pneumatics or bellows are glued with a warm flatiron.

Use very thin kid for pouches, white stockinette for pneumatics, motor bellows and tension governors, and heavy canvas bellows cloth for exhausters and reservoirs.

Always be careful to replace unseated valves exactly as you found them.

Shellac is good to fill up small splits in valve boards and similar places.

Lastly, use common sense, study each player before you undertake to handle it, and do not lose your nerve.

CHAPTER II.

ON PIANO REPAIRING.

One of the most important of the piano tuner's duties is the repairing of old instruments. Even to-day there are numberless old squares in the homes of people in moderate circumstances, which are still capable of being made fit for many years of service, and whose owners are unwilling or unable to afford the expense of new instruments. The same statement may be made to apply with equal force to uprights and grands. Everywhere the intelligent tuner finds pianos of every kind in a more or less wrecked condition; pianos that are too good to be discarded and equally too good to be sacrificed in a trade for new instruments. Such pianos are fair game for the good repairer, who is often enabled to restore them to something like their pristine vigor and thus earn good fees and much gratitude from the owners. The field for repairing is almost unlimited, and there is no tuner with an independent practice but should regard the repairing branch as most important to his reputation and pocket.

Nevertheless, it will be found that a knowledge of the essential principles of repairing is by no means as well developed or as evenly distributed among the tuners as it should be. This lamentable state of affairs arises largely from the fact that the factory offers little encouragement to one who may desire a knowledge of the conditions surrounding the deterioration and decay of old instruments, while the average wareroom is hardly much better off in this respect. Speaking from experience, it can be said that virtually nothing about repairing is to be learned in factories, although the knowledge of practical action finishing, regulating, stringing and tone-regulating, there gained, is of inestimable value. But the restoration of old instruments is a neglected art, and its practice must be learned generally through experimentation on the "subjects" found in the course of the tuner's daily routine. While the practical knowledge thus gained is useful enough to the practitioner, it is liable to be somewhat dangerous for the piano owner who entrusts the repairing of his instrument to a tuner whose experience and knowledge are together unequal to his ambition and enthusiasm. It is in the light of this knowledge that various manuals and pam-

phlets have been produced from time to time, the object whereof has been to teach the fundamentals of artistic repairing, and thus to save the ambitious but inexperienced tuner from the humiliation of doing bad work and perhaps spoiling an instrument altogether.

There is money to be made in repairing, and the good workman need never go with an empty purse. A small investment at the beginning is, therefore, worth while. First of all, consider the appropriate tools. If the tuner desires to undertake large and elaborate repairs, he should have some sort of a workshop, and this should be equipped with workbench, glue heater, racks and hot-box. A good set of cabinet-maker's tools, as well as the usual instruments for regulating and tuning, should also be provided. Thus equipped, the repairer may consider himself ready for business. Let us suppose that he is called upon to rebuild an old grand piano, which has suffered from the ravages of moths, mice, dampness and hard usage for thirty years. When the instrument has been delivered at the workshop, let us take a look at it and decide just what we are going to do with it. We will suppose, for the sake of argument, that the owner wishes to have

it thoroughly rebuilt, and has given the repairer *carte blanche* in the matter of expense. Not many piano owners will be found to be as accommodating as our supposititious one, but our purposes will be better subserved by supposing this to be the case.

Disregarding the condition of the outer case for the time, we proceed to take off the top and examine the upper surface of the plate, soundboard and strings. As we expected, the pins and strings are red with rust, indicating excessive dampness, the soundboard is split, and the plate is everywhere discolored with the combined effects of dirt and moisture. Generally, the spectacle is a sorry one. Now let us remove the action. What do we find? Hammers worn down flat, the highest in the treble almost or quite cut down to the wood, the dampers moth-eaten, the screws loose, the felts worn away, hard and brittle, the center pins working out of place, the key bushings almost disappeared, and the touch sunken, shallow and rattly. Altogether a most distressing sight, and one calculated to strike terror into the heart of whomsoever has to undertake its regeneration.

Let us now see what can be done with this poor, broken-down, old specimen. The first thing

to be done is to unstring our piano. We take a T-hammer and let down the middle string of each unison group from the treble downward, including one string from each of the two-string unisons in the bass. Then we go back to the high treble again and do the same thing with one of the other members of each unison group until all of these have been loosened. Finally we return once more to the top and let down the remaining string throughout. This process enables us to gradually lessen the tension without straining any part of the plate at the expense of any other part.

The next thing is to cut off the old strings with a cutting plier near the agraffes. Then all the old wire may be cleared away. The old bass strings, however, should be preserved entire and carefully hung up by their hitch-pin loops upon another piece of wire or stout twine, in the order in which they are taken from the piano. If any of the bass strings are missing, put in place of each one a piece of twine, similar in length, and with the places for agraffe, bridge-pins and hitch-pin carefully indicated by knots. In this manner the string-maker, who is to use the old strings as patterns for new ones, may be able to make up his set perfectly and without mistake, the place of the

missing strings being supplied as described. Send the whole set to the string-maker and a new and perfect one will be delivered to you in a short time.

When all this has been done the soundboard and plate are laid bare throughout their extent. They should then be well cleaned, first by blowing out with the bellows and then by washing with soap and water. All parts must be dried as soon as washed, and wetting of the wrestplank must be avoided. On no account use alcohol to clean the soundboard or plate.

Then see if it is possible to tighten up the various screws and bolts that secure the plate. When these have been examined, turn your attention to the soundboard again and prepare to remedy the faults found therein. You will observe several cracks extending in different directions. Open these up carefully with a sharp knife, so as to make the width of each crack uniform, and then glue in a thin strip of soundboard lumber, technically known as a "shim." Strips of this kind properly cut will be supplied by any soundboard manufacturer or by the bellying department of any factory. These "shims" are always cut with one edge wider than the other. When mending

cracks in a soundboard, then put in the shim with the thin edge first, taking care to have it well warmed and seeing that the glue is hot. Punch the shim well down into the crack and then dip a small brush into the boiling water in the gluepot and apply it to both edges of the filled crack. This will swell the wood, so that the shim will fit snugly. Then let the job stand until the next day, at which time you may take your sharp knife and trim off the edges of the shim as neatly as you can.

Now, if you should find that the belly-bridge has split, it will be needful to replace the damaged portion. So you had better make a pattern with paper and pencil by rubbing the latter over the former, which has been laid on the cracked portion of the bridge. Allow for the widening of dimensions through the cracking. Then send this pattern away to a soundboard maker with directions to make it up in bridge lumber. Take care to have it only about one-fourth of an inch thick, however. Then cut out the broken part with a very fine saw to the same depth, and when the bridge part comes back to you glue it in place and secure it with screws. You must, of course, bore for the bridge-pins and drive these in before secur-

ing the new piece in place. Also don't forget to blacklead and burnish the surface.

If a crack in the soundboard shows immediately underneath the belly-bridge, fill the crack in the usual way, but from the back, and when the glue is dry, drive a screw into the bridge on both sides of the crack and place a wooden soundboard button on each screw.

Before calling the soundboard department finished, take a careful look once more at the wrestplank and other parts and assure yourself that they are tight and secure, and that there are no cracks therein. If a wrestplank is badly split, as sometimes happens, it may be very difficult to do anything for it except send the piano to the factory; otherwise a split section may sometimes be sawed out, remade and replaced like a split bridge section. But great care and skill are necessary for such work. If it is merely a case where the wrestplank is slightly and superficially cracked along its outer surface (as may be seen in open wrestplank constructions), then it may be better simply to remove the pins, ream out the holes slightly and plug them up with maple dowels, well glued in. In this way it is possible, not only to provide the tuning-pins with new and firm resting

places, but also to reinforce the weakened wrestplank. An injury to a wrestplank that can be gotten at and glued up may be undertaken with a fair prospect of success, but it is bad to monkey with wrestplanks unless one knows exactly what one is doing.

Now, when you have done everything needful with the soundboard, wrestplank, plate and bridges, take a look at the under side of the board and see if there are any loose ribs. If so, there will be rattling and buzzing when the piano is played. This will particularly occur when the rib springs up in the middle portion from the surface of the soundboard, owing to the loosening of glue or through warping. In order to remedy such a fault it is necessary to fill up the space left between the rib and board by the springing of the latter. Use a strip of spruce of suitable size and glue this in the space referred to. Secure with a screw.

RESTRINGING.

It is now time to consider the matter of restringing. If you have filled up and rebored the tuning-pin holes, there will be no difficulty in following out the traditional methods of factory stringing.

On the other hand, if you intend to use the old pins in the old holes, it will be necessary to take considerable more care about your work, in addition to all usual precautions. If there is not a fair space between the eye of each pin and the wrestplank, then you cannot use the old pins at all, for it will be necessary to hammer them in further than their original position in order to tighten them when the new wire is put on, and this cannot be done when they are already sunken deeply into the wrestplank, for in this latter case the extra hammering will drive the pins so far in that an angle will be formed by the string and agraffe so acute as to insure breaking when the string is pulled up to pitch; so that if you see it to be inevitable that the pins be driven in very far it will be best to plug up the holes and rebore so as to have the advantage of new pins in new holes.

With most pianos you will find that the stringer indicates the number of wire that he is using at any place by writing figures to correspond on the wrestplank or plate at the points where each new number is brought into use. You can, of course, use these numbers for guides in stringing your piano, but if they have been omitted you will have

to note, by means of a music wire gauge, where the changes in number occur.

Be careful to use only the best wire and, whatever happens, keep hot and perspiring fingers away from direct contact. If necessary, use a pair of rubber gloves. If you are using new pins in new holes, wind the wire round the pin with three coils before inserting the latter in the hole. Be careful in driving the pins that you do not twist them, and remember that the pin must be gradually driven in rather than forced violently.

If you are using the old pins, be careful to have only as many coils of wire on each as will insure a fair space between the last coil and the surface of the plate or wrestplank. Drive the pins well in with a square, firm blow of the hammer and pull the wire up tight at once.

See that all the pins are at the same level and hammer down any that remain high. Set the strings down well at the hitch-pins and on the bridges and see that they fit tight and snug into their proper places.

When you come to the bass strings, be particular about handling them, and especially about the manner in which you drive the pins. Be careful that you do not get the bass strings mixed up.

Leave them on the wire upon which they are strung when sent to you and take off only one at a time.

When you have strung the whole piano in this way, space out the string groups in approximately the distances that they actually occupy. (If the piano has agraffes this is unnecessary.) Then it is time to take up the work of bringing the strings approximately to pitch. This is what we call "chipping."

"CHIPPING."

In "chipping" the strings which you have just placed in the piano, begin by drawing up the middle C group well above concert pitch and then rapidly pull up the others, above or below, estimating the pitch of each semitone and correcting each C by middle C as you go along. Do this as quickly as you can and then rub down the strings with a piece of wood covered with leather.

Now repeat the chipping, but this time more carefully. You will find that the strings have all stretched out, so as to bring the pitch away down again. So pull middle C again above concert pitch and then tune as usual, chipping the strings with your fingers and laying the bearings as well

as you can. Then rub down the strings again and let them stand for twenty-four hours. Then repeat the process, leaving the pitch as you find it, unless it be much below concert pitch. You can then begin to think of rough tuning.

“THE KEY-FRAME.”

Between the second and third chippings, however, it will be well to look at the action. As will be remembered, we found this in a parlous state. The hammers, felts, pins and bushings alike showed the ravages of moths and mice, while the shrinking of the wood had left every screw loose and rattling. We also found an analogous condition to exist in the keyboard, and it will be well to begin our repairing here. Let us remove the screws that secure the action frame in place and remove the action entire. This leaves the keyboard exposed. The keys should then be removed and the bare keyboard examined. Take off the old, moth-eaten punchings and blow all dust away with a bellows. Then, when the frame is well cleaned, brush a little benzine into the spaces between the rails and key-pins. This will kill off the moth eggs.

Then put on new punchings of cloth on the front and balance rails, but leave off all paper punchings for the present.

Now clean off each key carefully so as to remove all traces of moths, and replace the set on the frame. Examine the keys and you will find that they rattle considerably on the balance-pins as well as in front. A temporary remedy for the rattling on the balance-rail may be obtained by driving small wedges, like shoe pegs, into both sides of the balance-pin bushings, but this sort of work is shiftless and clumsy. Instead of this obtain a set of key-tops from a supply house and glue them on the keys in place of the old tops, which can easily be removed with a sharp knife. If it is not possible to obtain new key-tops you must rebush the old ones. Do this as follows: After removing the worn out pieces of bushing cloth, cut new pieces of proper size and glue these in place, securing each with a little wooden block very slightly thicker than the balance-pin.

Unless the front bushings are entirely worn away, the keys can be regulated at this end by turning the front rail pins with a key-spacer. These pins are oval in shape, and when turned occupy a larger space within the bushing aper-

ture, thus regulating the motion of the key at its front end. If the bushings are altogether worn out, make some little wooden blocks, slightly wider than the opening in the key, each provided with a plug at one end adapted to go up into the opening of the key. This will secure the bushings while the glue is drying.

When these faults have been remedied, look to the condition of the ivories. Replace any that are missing or defaced and whiten the others according to the directions given in the next chapter. Touch up the black keys with French varnish.

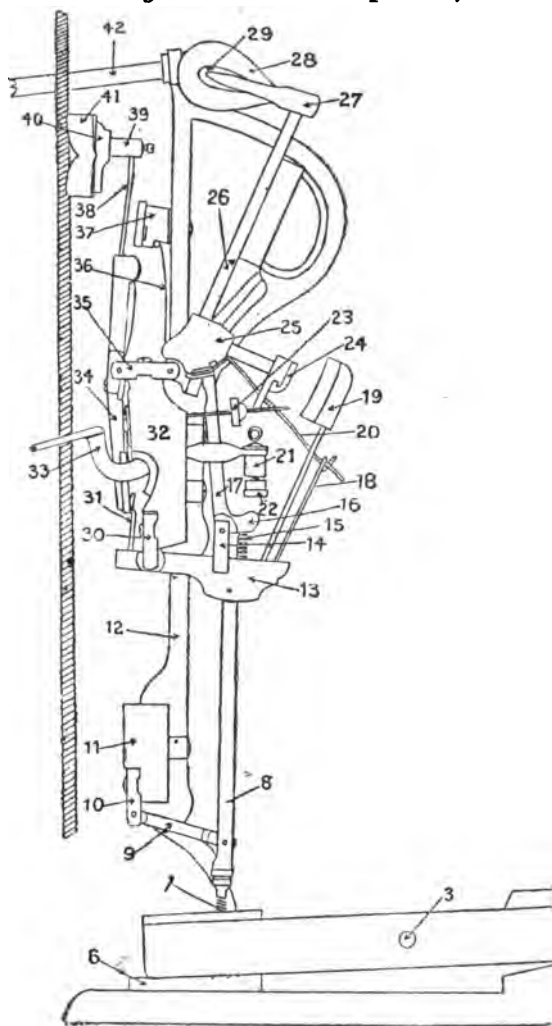
Then take a number of little pieces of lead weighing $2\frac{1}{4}$ ounces each and fasten one into the back of every key. This will be equivalent to the weight of the action and will enable you to ease up or level the keys.

Begin by trying the tightness of each key on front and balance-rails, and fix things so that there is just a very little play between the openings and the pins. Ascertain this by shaking, and regulate with the key-pliers.

After the keys have been tested for ease of motion, the work of leveling them can be taken up. In order to do this properly we must use a straight-edge made out of thin soundboard lum-

ber, as long as the stretch of keys from bass to treble, and light enough to rest firmly on the fronts of the keys without bearing them down.

Then place under each extreme bass and treble key a block of wood, perforated to allow the front rail-pin to pass through. Let each block be three-eighths of an inch high. Take out or put in enough punchings on the balance-rail of each extreme key to cause it to hold firmly on the block of wood. Then use these extreme keys as supporting points for the operation of the straight-edge. When all the keys have been brought level with the two end ones the job will be complete. When you first lay the straight-edge over the fronts of the keys you will probably find that they sag down considerably toward the middle. In this case build up the level of the balance-rail by putting under it some slips of paper or cardboard of appropriate thickness. This is more rational than to attempt to level up each low key individually. When an approximate level has been attained in this way, take each key individually and observe its relative level. Test by shaking the straight-edge on the keys. If they shake when the stick touches them they are too high, but if they are too low you will see a space between them and

**FIG. 5.**

UPRIGHT ACTION.

- | | |
|---------------------------------|--|
| 1 Key | 22 Regulating button and screw |
| 2 Key frame | 23 Jack stop rail |
| 3 Key lead | 24 Back stop |
| 4 Front rail pin and punching | 25 Hammer butt |
| 5 Balance rail pin and punching | 26 Hammer shank |
| 6 Back rail cloth | 27 Hammer molding |
| 7 Capstan screw | 28 Hammer top felt |
| 8 Abstract | 29 Hammer under felt |
| 9 Abstract lever | 30 Wippen flange |
| 10 Abstract lever flange | 31 Spoon |
| 11 Lower action rail | 32 Middle action rail |
| 12 Action bracket | 33 Damper lifting rod |
| 13 Wippen | 34 Damper lever |
| 14 Jack flange | 35 Combination flange for damper lever and hammerbutt. |
| 15 Jack spring | 36 Spring rail spring |
| 16 Jack knuckle | 37 Spring rail |
| 17 Jack | 38 Damper wire |
| 18 Bridle wire | 39 Damper block |
| 19 Back check | 40 Damper head |
| 20 Bridle tape | 41 Damper felt |
| 21 Regulating rail | 42 Action bolt |

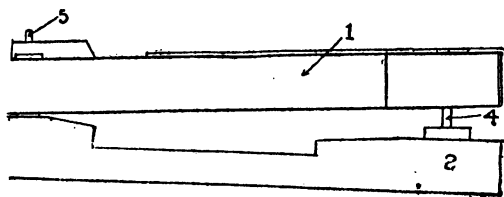


FIG. 5.

stick. Build up with punchings on the balance-rail and cut down by planing off the bottom around the balance-pine holes.

“THE ACTION.”

When the keys have all been leveled lay aside the leaden blocks that were driven into the backs of them. Then take up the action, clean it well and, after replacing it on the keyboard, proceed to examine it as follows:

First of all look to the condition of the various pieces of felt and leather that are used in the more remote parts. Pay particular attention to the hammer knuckles, back checks and repetition lever cushions. The felt or leather on any or all of these may need replacing, and you should not hesitate to do this where necessary, if you intend to make the rebuilding thorough and permanent. In replacing such felts and leathers take care that the new pieces are of the same thicknesses as the old originally were. You can test this by looking at the corners and edges of the old pieces. Then look at the center pins and their bushings throughout. If you find the latter enlarged through use put in thicker pins. Where bushings are entirely worn away, you can usually get new flanges fitted

to whatever action the piano contains from the manufacturer of that action, or from the makers of the piano. Otherwise you may have to do your own rebushing. This is not very easy. The best plan is found in cutting a piece of bushing cloth to a point and then making one of the edges thinner with a knife, well sharpened. Glue the thinned edge to the other, thus making a conical shaped funnel, the apex of the cone being where the cloth was cut to a point. Then force one end of this funicular piece of cloth into the bushing holes of the flange, first placing a little fairly thick glue around the inside of the holes. Secure the position of the new bushing with a center pin driven through the holes, which will secure the cloth until it is dry. Then cut and trim to suit.

Lastly, consider the state of the hammers. You will very likely find that a complete new set is desirable. Now, the hanging of a new set of hammers is not the easiest matter in the world, and one must be very careful in setting about this kind of work. First, of course, remove the end hammers of each section and send them to a hammer maker, together with a drawing showing the dip or angularity of the scale. If the piano be a good, recognized make, as most grands are, you can

GRAND ACTION.

1 Key	22 Repetition lever regulating button
2 Key frame	23 Repetition lever stop
3 Key leads	24 Hammer cushion
4 Front rail pin and punching	25 Top action rail
5 Balance rail pin and punching	26 Hammer flange
6 Back rail cloth	27 Hammer shank
7 Capstan screw	28 Hammer knuckle
8 Wippen bottom knuckle	29 Top repetition lever stop
9 Action bottom rail	30 Hammer molding
10 Wippen supporting flange	31 Hammer under felt
11 Wippen	32 Hammer top felt
12 Jack knuckle	33 Damper wire
13 Jack	34 Damper head
14 Regulating rail	35 Damper lever
15 Regulating button screw	36 Damper lever flange and spring
16 Jack regulating button	37 Damper lever leads
17 Jack stop	38 Damper block
18 Repetition lever support	39 Damper wire
19 Repetition lever	40 Damper head
20 Repetition lever spring	41 Damper felt
21 Jack spring	

FIG. 6.

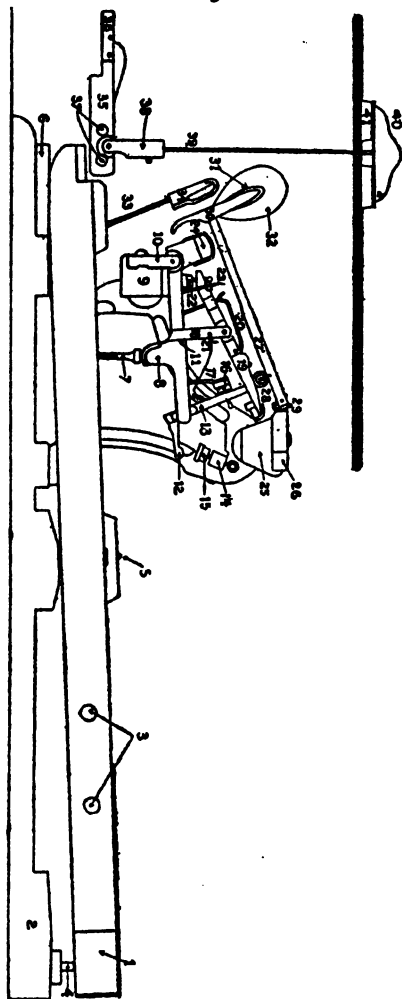


FIG. 6.

probably get a set of hammers bored at the proper angle by applying to the makers. When these are received proceed as follows: Take off the hammer from every alternate shank by means of the extractor, or else by heating the shanks until the glue that holds the hammers is melted. The former process is far preferable. Then take the new hammers corresponding to the old ones that have been removed, fit them on the shanks and place the action in the piano, noting how the new hammers meet the strings. If all seems well, apply glue to them in groups of three or four at a time, immediately setting the action back into the piano at each gluing so as to test the hang of the hammers. When this has been done throughout, repeat with the remaining hammers, and put the action away for the rest of the day to dry.

Now look at the damper action. It is a perfect nuisance generally to get the damper levers and flanges out of a grand case, if this be necessary, but it is usually possible to effect ordinary repairs without having to do this. If you have already decided to use new dampers and heads, you will, of course, send enough specimens of the old set to enable any action maker to send you new heads and new felt cushions for a complete set. When

these have been placed in the damper blocks below, test to gauge their straightness on the strings and bend the wires until every damper lies even and firm on its string group, covering it well and damping as is proper. Also note whether each damper rises just as quickly and as far as every other when the sustaining pedal is depressed. Correct irregularities in these motions by bending the wires or altering the depth of the damper wire in the damper head. Also pay attention to whether the damper blocks rise evenly, and remedy this if they do not.

Also correct excessive lost motion between the pedal foot and damper levers. Glue suitable pieces of felt on the ends of the pedal sticks or in other suitable places to take up this lost motion. Also observe whether the rods for the other pedals work freely and without noise. Blacklead them when necessary. Look to the spring that pushes the key-frame when the left-hand pedal is released and strengthen it if necessary by putting paper or cardboard between it and the side walls of the piano, so as to bring it out a little nearer to the key-frame.

Then take up the action again. Clean off the remains of glue, if any exist, and get ready to do

your action regulating. This is a task that is by no means easy, even to an expert, and the inexperienced tuner will have all kinds of trouble, unless he knows exactly what he is doing at all times, something which he is not very likely to know, if, indeed, we assume him to be inexperienced.

Before proceeding with the task of regulating, please take note of what the action is supposed to do. The let-off of the hammers, the rise of the repetition lever towards the hammer knuckle, the position of the jack midway in the repetition lever groove, the strength of the repetition lever springs, the distance of the back checks from the hammer tails ($1/16$ inch), are among the most important details to be observed. The depth of touch should be preserved at three-eighths of an inch, and there should be enough "after-touch" to cause the hammer to leap upwards after the let-off from the string when the key is pressed down slowly and firmly as far as it will go.

In taking up a grand action for the purpose of regulating it, we must pay particular attention to the points just now considered. We begin by adjusting the lost motion through the capstan screws, or rockers, noting that the level of the hammer is adjusted so that the shank stands

about an eighth of an inch above the cushion that belongs to the repetition lever. This practice is different from that which obtains with upright and square actions, in which latter the hammer shanks rest directly on a cushion-rail.

Next attend to the let-off of the hammers. These should be arranged to escape from the jack when they have approached to a distance of $\frac{5}{32}$ of an inch from the string. The easiest way to do this work is by fixing a test frame above the action on the workbench, arranged with a wooden rail to be suspended above the hammers at the measured height of the strings. The proper measurements may be made from the inside of the piano case so as to obtain the dimensions of the test frame.

Next turn your attention to the back-checks. It is necessary that the hammer should be well and securely caught and held by the checks in order that blocking may be avoided. Nor is it less essential that the catch of the hammer should occur at precisely the right place, in order that its position may always correspond with the regulation of the other parts of the action. Let the checks lie as near as possible to the hammer tail, and see that the catch occurs when the hammers have fallen away from the strings to a distance of

three-quarters of an inch. In connection with the catch of the hammer, be it observed that the position and regulation of the escapement lever is a very important part of the checking operation. The springs that actuate this lever must be sufficiently strong to cause the hammer to rise a little when released, or when the key is pressed down firmly as far as it will go. In other words, the springs must be strong enough to lift the hammers slightly by their own power. Test these springs and strengthen them if necessary by bending with a damper-spring bending iron or similar tool. Observe also whether the repetition lever is properly adjusted as to depth of descent at the back end. When the hammer is caught and held by the check, there should be a small space left between the repetition lever and the little nook found at that end of it.

The other end of the escapement or repetition lever must be considered likewise, and it will be seen that there is a little button, provided with a screw thread, fastened into the hammer butt and touching the front end of the lever. The object of this little button is to prevent the escapement lever from coming up too high, as in that case it would tend to force the hammer against the string

after the catch of the check, thus causing a rebound. The function of the repetition lever in a grand is to make the first lifting effort on the hammer, and its position is such that it can force the hammer against the string unless regulated properly, quite irrespective of the position of the jack. Screw down the little button on top of the hammer butt until it stops the repetition lever as soon as the hammer has approached within a little more than one-eighth of an inch from the string. Practice will enable the regulator to determine this distance with great nicety.

“TUNING.”

Now, when you have well and carefully done all this, you may consider your task complete as far as the action regulating is concerned. You now may turn your attention to the tuning and tone regulation. If you know your business you will not have neglected to give the piano at least one rough tuning before the action regulating. This rough tuning should be done in such a way as to test out thoroughly the stretching powers of the strings, and the tuner should not be afraid of hurting his fingers by pounding. As soon as the regulating of the action is finished tune again,

and then once or twice more at an interval of two or three days. The piano may now be tone regulated. But before taking up this task pay attention to a few remarks on the subject of tuning new wires. The pitch must be tested constantly, and if the piano is to be maintained at international pitch, as I have throughout assumed, it must be continually drawn a little above this, and allowed to sink to international after it is placed in its owner's home. Moreover, the strings must be well pounded and the pins well turned. The kind of tuning that is known as "springing the pins" must be avoided, nor will any other process of pin manipulation avail except plain, honest tuning, and good pounding of the strings down to pitch. Otherwise the piano simply will not stay in tune, and the reputation of the repairer will suffer accordingly. Another thing: The more tunings you can give the piano the more satisfactory will be the result in the end. If you have plenty of time, and if the amount of your bill will justify it, you had better tune six times and be sure than three and be sorry.

"TONE REGULATING."

Voicing or tone regulating is a task demanding the highest qualities—the longest experience and

the greatest skill of any of the complicated operations of which the sum is the modern piano.

The sandpapering of the felt must be done with a steady hand and a straight held file. I prefer to take each side of the hammer separately, so as to bring the work to a head at the crown of the hammer. Then the remaining skin of the felt can be smoothed away without doing any harm to the surface or spoiling the shape. Take off as little as possible and see that you have a sharp sandpaper file, changing the paper whenever necessary. Use two files, and have the first coated with No. 1½ paper for the rough work, which should then be smoothed with another file covered with No. 00 paper.

When you begin to soften the hammers, first test them in the piano by means of both hard and soft strokes on the keys. If you find the under cushion of felt to be very hard, dig into it with a felt picker containing only two fine needles for treatment of the upper surfaces. Dig straight down into the felt, making the strokes with the picker as if they were the spokes of a wheel. Do not gouge out the felt or "pick up" the upper surface of the hammer. This sort of work may do for a while, but has no permanency. Try

throughout to soften the hammers only enough to obtain a tone moderately mellow and full. Take care that it is neither too brilliant nor too mushy. Careful preparation of the hammers by digging well into the depths of the felt will assist here greatly. When you come to even up the tone, it will be necessary frequently to withdraw and replace the action. Make little pencil marks in the middle of the ivories, or at their top ends when you wish to indicate a black key, whenever you find a hammer needing attention, and when you have six or more marked this way, withdraw the action and subject them to such treatment as they need, then erase the marks, replace the action and test again. Watch continually lest you make the hammers too soft. When you have done all that you can, tune once more, and then send for your customer. Your piano ought now be near an approach to a new one.

“IVORY KEY POLISHING.”

It is a very useful thing to know how to clean and polish ivory keys on old pianos. This is a task that often is required of the piano tuner, but there is considerable variety in the methods

employed, as well as in the ideas which tuners generally have regarding them.

Upon examination of the keyboard of an old piano, it will often be found that the ivory head-pieces are worn into hollows from long years of use. When these hollows are so deep as to make it impracticable to scrape the old keys, then new ivories must be glued in their places, otherwise the tuner may set about removing the yellow stains from the keys in this manner: First, let the black keys be removed. Then fasten down the row of white keys by means of a strip of wood running across them just in front of the balance-rail. After this take the ivory scraper, which is a square piece of steel rubbed down true on the edges with an oil stone, and with one end scrape each key from the back toward the front, until all the yellowness has been removed and a smooth, level surface remains. Considerable skill is needed in this operation, as it is very easy to scrape slantingly, so that the resulting surface on the key will be out of level. Of course, this must be avoided at all costs, and in order to obviate the possibility of this sort of trouble, another and longer but easier method may also be used. Take a piece of wood, about six inches long, four inches

broad and an inch deep. Cover one side of it with No. 11½ sandpaper, and with the block thus formed rub the ivory backward and forward, taking care to keep the block square and level on the surface. By this means the yellowness will gradually be removed until the whole surface is white. More time will be consumed in this way, but the result is far less likely to be disastrous. After rubbing with rough sandpaper, the operation must be repeated with a much finer number of paper, such as No. 00. This is to remove the scratches left by the first operation, so as to leave a smooth surface for the polishing.

In order to perform this last part of the work, take a piece of coarse rubbing felt and fasten it to a suitable block of wood. Moisten the pad thus formed with alcohol and sprinkle whiting upon it, then rub as before, keeping the pad moist with the alcohol. A smooth polish will quickly be obtained. After everything is finished see that the keys are not wetted at their openings, and scrape away carefully all remains of whiting, and all dust.

In doing anything of this kind, it must be remembered that the surface of the keys has to be kept level, whatever happens. Only a very slight

sidewise movement of the hand is required to make a depression in the surface of the ivory. Moreover, the old surface is likely to be thin and worn down, so that carelessness in handling the sandpaper block may be expected to cause even a rubbing through in some part of the key. This must be looked after at all costs. Of course, the scraper provides the quicker and more accurate method, but beginners are likely to do more harm than good with this instrument until they have learned its proper use. Various liquids are also in use, the object of which is to smooth the surface of the ivory, as well as to polish it. Experience seems to show, however, that the simple method outlined above will answer for all purposes, provided that enough care be exercised in the different operations.

It will sometimes also be found that the fronts of ivory keys are broken and chipped. In such cases glue on new ivories. Always use pure white glue. If necessary, mix whiting with the glue.

In connection with the present discussion of the minutiae of piano repairing, and as a digression therefrom, I invite attention to the following letter from a Michigan correspondent, who prefers that I suppress his name:

“Dear Sir:—I would be very glad if you would take up some time the matter of the advisability of repairing pianos outside of the factory when a new pin-block or sounding-board is required. Is there any reason why this line of repairing could not be accomplished as successfully and artistically in a well-equipped shop as in a factory? Also, would it pay to equip a shop for this purpose? There is plenty of this kind of repairing to be had in this locality, and I have been thinking of building and equipping a shop and obtaining the services of a first-class carpenter or cabinet-maker whenever necessary. An answer will be great appreciated.”

Undoubtedly a well-equipped repair shop ought to be capable of caring for any kind of repairing, even to the point of absolute reconstruction. Of course, everything depends upon the knowledge, experience and skill of the man at the head of affairs. In beginning the present talk on piano repairing, I spoke of the advantages to be found in the establishment of complete shops, and I have no doubt whatever that profit and pleasure alike may be derived from this kind of work.

Recollect, however, that such work as is implied in the rebuilding of a piano demands rare skill,

and even this is of little value unless backed up by the best facilities. It is not an easy matter to fit up a new pin-block or soundboard into an old piano, nor should work be attempted by anyone who has not had practical experience in bellying. Enthusiasm alone will not compensate for lack of the requisite skill in piano-making. And, anyhow, I am often inclined to think that good repairers are born more often than made.

The equipment of a repair shop is a matter for careful planning. Such a place should be dry, sunny and well warmed. It should be fitted with racks for varnished work, a steam-box for warming parts which are to be glued, a practical glue-heater, benches and tools, including, if possible, a small saw and drill-chuck driven by power. A small space should be partitioned off for varnishing.

It would not be a good plan, I fear, to trust very much to the tender mercies of carpenters. A thorough cabinet-maker, accustomed to fine hand-work, might often be employed to advantage, but the piano man himself must oversee, as he must be responsible for, every smallest detail.

Summed up, the whole thing comes to this: If your ability is equal to the task, and you are able

to invest the necessary capital, a repair shop should be a good, money-making proposition. Be very sure what you are doing, however, before you start in.

TUNING AS SCIENCE AND ART.

CHAPTER I.

THE PROBLEM.

The first step towards the correction of an error has been taken when we have defined and limited the nature of the corrective process. And this cannot be done until the nature of the error itself has been duly defined. So in the solution of any problem whatever, the enunciation thereof is the first essential. We must know, in short, just what it is that we have to attack, and likewise exactly what it is not. We cannot then begin the present chapters better than with an attempt thoroughly and clearly to delimit and define the nature of the problem which the piano tuner is called upon to solve. And the vital importance of this step is even more clearly recognized when it is remembered that the principal reason for the latter-day decadence of tuning as a fine art is to be found in the all too frequent ignorance of just this matter, namely, the exact nature of the problem.

Nor can we entirely attribute this lamentable state of affairs to the ignorance or perversity of the present generation. When the authorities themselves are so far from substantial agreement, who shall guide the learner aright? Certainly he can hardly be expected to discriminate between false and true teaching. Yet he will be able to make his own path much more clear and smooth when he understands from the start just what it is that he has to learn, and why.

The problem of tuning the piano, then, is first to be stated as comprehensively as possible. We may enunciate it as follows: *It is required to manipulate the strings of the piano in such a manner that the pitch of each shall bear such harmonic relation to the pitch of every other as to permit of agreeable chord structure in any and every tonality used in music, and likewise shall allow of free modulation from any given tonality into any other tonality, without bringing into being unduly dissonant chords.*

Now the observer will at once note that the above definition (which may be considered as sufficiently accurate) is very far from being rigidly scientific. It refers to vague and indefinite terms. It speaks of "agreeable chord structure" and

“unduly dissonant chords,” and so implies that there are such things as “disagreeable chord structures” and “duly dissonant chords.” Now any one who knows anything of the science of harmony is aware that, truly speaking, a chord is either consonant entirely or altogether dissonant. Consonance and dissonance are really strict and definite terms. Therefore, when we imply the existence of states not comprehended within the strict definition, we undoubtedly refer to matters not altogether within the rigid lines of musical science. And the conclusion is no less true than inevitable. For reasons which we shall discuss later on, and which have their rise in the constructional limitations of the piano, the art of tuning is based upon a scientific compromise; upon a sort of arbitrated award between the contending claims of harmony and musical mechanics.

In fine, the tuner is obliged to do a great many things that would be inexcusable, and indeed unnecessary, were he not bound down to the existing thirteen semitones which form the octave in keyed instruments. As we shall come to show later on, such a number of semitones is entirely inadequate for the task of expressing every possible interval in every possible tonality. Thus is a

compromise with musical truth made obligatory, and thus does the art of tuning largely depend for its successful practice upon the skill with which this necessary compromise is made. Understanding this, we shall have no difficulty in perceiving the necessity for a thorough acquaintance with the methods of musical tonality construction, inasmuch as we cannot properly undertake the distortion of chords and intervals, until we understand, in the first place, how they are originally constructed.

To recapitulate, the problem of tuning is essentially the problem of so distorting the structure of each member of the true musical tonalities as to permit of modulations and chord formations that would otherwise be impossible of expression upon the piano. Obviously, work of this sort cannot be undertaken until we know a great deal about the general make-up of the various tonalities used in music. And our knowledge must be of their physical nature rather than of their other properties, since it is this nature which we are to learn how to change in accordance with our purposes. The first step is clearly an examination of the nature of the musical sounds of which tonalities are built up.

SOUND.

“O! Sound, thou art the echo of a word
That broke the primal stillness by command—
An echo, through whose strains our souls have
heard
A promise of the choral raptures grand,
That, voicing love and praise, forever rise
In Music’s natal home beyond the skies.”

These beautiful words, quoted by Dr. Zahm in the preface of his work on Sound and Music, give us an ethereal and spiritual view of the nature of sound, which, however, is not so fanciful as it may appear. For the sensation of sound—sound as a sensation—has absolutely nothing of objective reality. It is a sensation generated within the secret passages of the brain by a series of motions engendered by the action of air particles upon the auditory apparatus. Of the nature of this sensation or of the precise means whereby it is transformed from physical motion to physiological sensation we are profoundly ignorant. But we are not less ignorant of the nature of the transformatory process as regards any other kind of sensation. In fact, there is open to us no way of crossing the line which divides the physical

action of the cerebral hemispheres from the physiological sensation therefrom arising. Therefore, we must needs avoid further consideration of it.

But it will be observed also that we have to consider sound, not only as sensation, but also as motion. It is the motion of the air, excited by external objects, and communicated to the auditory apparatus, that produces the sensation, however mysteriously. Now this physical aspect of sound must be recognized, although it is not strictly correct to call this physical process by the name of "sound." For sound is the result, the sensation. The physical cause of the sensation is the "sound-process," nothing more.

Nevertheless, custom has sanctioned the rather loose terminology here adverted to, and we shall therefore not cause further confusion by an attempt at strict and punctilious correctness.

(I might mention here that a recent critic takes me to task for stating in "Theory and Practice of Pianoforte Building" that sound has no objective existence. It is regrettable that the unscientific mind is entirely unable to grasp so obvious and implicit a distinction as that mentioned above.)

The distinction between sound as sensation and as physical process is parallel to that which exists in all other cases of sensory phenomena. Whether we consider the sensations of sight, touch, smell, taste or hearing, we observe the sharp discrimination between the cause and the effect — between the physical process and the physiological result. In the case of touch, taste and smell, matter in some form provides the cause, while motion of some sort is the predisposing agent in the case of sight and hearing.

Sound, then, physically considered, is a mode of motion. So are light and heat. But the kinds of motion that generate the sensation of light and heat are incapable of affecting the auditory apparatus so as to produce sound. So that we cannot hear colors or heat; nor can we see sounds. The rate of motion required for the production of heat is very much greater than that of the highest sounds, and the speed of motion essential to the production of light sensations is far greater again.

Sound is a form of motion, wherein the particles or molecules of the air are excited out of a state of equilibrium. When any elastic body is so excited the molecules partake of a reciprocal vibratory motion, which continues with progressively

diminishing intensity until the body again comes to rest.

Observe that the kind of motion is always vibratory. That is to say, it consists of a swing in one direction, a return to the position of equilibrium, and a swing in the opposite direction, the lengths of the divergences in each direction from the central position being equal. The motions which produce sound, then, are vibratory motions of the molecules of the air; sound is produced by molecular vibration of the atmosphere.

Now this vibration can be excited in the atmosphere by the shock or friction engendered by some solid body. If, for example, we take an elastic piece of steel, and shake it back and forth, it vibrates. When it swings in one direction it pushes the nearest layer of air away from it, and this body of air rushes back when the direction of the swing is reversed, while the air adjacent to the new position is in turn pushed away, and in turn rushes back. Now, if the steel strip makes ten vibrations per second it is obvious that the adjacent air will be excited into ten vibratory corresponding motions in the same length of time. When the number of such vibrations per second is sufficiently great—above thirty—the ear begins

to communicate them to the brain as a collected and uniform result, and the sensation of sound is brought about.

It will also be observed that the motion of the air is in the form of alternate condensation and rarefaction, as each layer rushes back and forth in obedience to the shocks inflicted upon it by the vibrating body.

When we begin to consider sound in reference to certain particular manifestations which have especial interest for us—when, in short, we consider musical as differentiated from non-musical sounds—we find a number of interesting phenomena. Musical sounds are distinguished from such as are non-musical from the fact that the former are propagated by periodical vibrations, while the latter take their origin from non-periodical or confused series of vibrations. In the first of the present articles we discussed the nature of these vibrations of the molecular particles of the air. It now remains for us to distinguish between the various kinds of sounds that are produced in this manner. As already stated, the distinguishing characteristic of the musical variety of these sounds is their periodicity; that is to say, the regularly recurrent nature of their generating vibra-

tions. The musical sound, in fact, is produced by vibrations which follow each other in regular and definite sequence. As we shall show later on, the gravity or acuteness of musical sounds varies as the frequency of their generating vibrations, and the lowest frequency of vibration which produces sounds audible to the human ear exceeds twenty per second. A smaller frequency is inaudible, for the reason that the ear is unable to blend the vibrations into one coalescing sound. When the frequency exceeds twenty per second the effect upon the ear is that of a single sound.

If we experiment with a wave siren, this fact becomes at once obvious. The wave siren is an instrument which delivers puffs of air at any frequency desired through a suitable receiving apparatus. By means of a counting mechanism the number of puffs produced per second may be read off on a dial, so that it is possible to note exactly how many are required to produce any given sound or musical tone. When the siren is operated very slowly the puffs of air at first produce no single sound, but when more than twenty per second are coming from the instrument they begin to coalesce, the resulting sound being very grave. As the speed of the siren is increased the sounds

become progressively higher and higher until when the speed of about twenty-five thousand is reached the sound ends in a sibilant hissing, and becomes inaudible.

The audible compass of musical sounds, then, ranges from those that are produced by about twenty periodic vibrations, to such as are generated by about twenty-five thousand in the same time. But the practical compass of musical sounds, the compass which is used in the performance of music, is not so great as this. The lowest tone of the modern piano has a frequency of about twenty-seven per second, and the highest does not exceed four thousand one hundred at the same pitch, the sounds in question being the lowest A and the highest C, respectively.

It is necessary that we should investigate somewhat the laws that govern the frequencies of these musical sounds. The first of these has already been indicated. It is not essential that we should undertake a demonstration of this law, and the bare statement will be sufficiently obvious. It is as follows:

The pitch of a musical sound varies as the number of vibrations per second.

This is the first canon of musical acoustics, as

applied to the purposes of the present investigation. We shall at present content ourselves with stating this law and proceed at once to note what deductions may legitimately be drawn therefrom.

LAWS OF SOUNDING STRINGS.

Sound is produced through the agency of numerous bodies. While it requires the interposition of some elastic fluid for its propagation, the first step in its production is taken when some body is set into vibration by an external agency. Thus, strings, rods, plates, bells, columns of air and other bodies are capable of being set into vibration in such a manner as to influence adjacent layers of air and thus propagate and transmit sonorous waves to the ear. Our investigations relate to the commonest, almost, of these agencies; namely, to vibrating strings. In music, at least, it may safely be said that stringed instruments, in some form or other, predominate in number over all others. Thus the nature and governing laws of strings present problems, not merely of immediate interest to ourselves, but of essential importance to the science of music in general.

We have already stated that the pitch of a musical sound—by which we mean its relative

gravity or acuteness—varies as the number of vibrations per second of the string or other sonorous body. A simple experiment will demonstrate that pitch is also dependent upon another factor; namely, upon the length of the string. If a rope of twenty feet in length be stretched tightly between two supports and then be struck a sharp blow, it will be set in vibration. But the frequency of the vibrations will be slow; we shall have no difficulty in distinguishing each vibration of the rope. In fact, there will probably be slight difficulty in estimating the frequency by the eye alone. If now we diminish the length of the rope by one-fourth we at once observe a sensible increase in frequency, and as we continue to diminish the length the speed of vibration is seen to increase progressively. Now let us carry the argument a little further. Suppose that we have a string of any given length and tune it to any given pitch. Then, by comparing this pitch with the same sounded on a wave siren, we may see just how many vibrations per second are performed by this string at the given pitch. Should we then take another similar string and tune it to the octave above, we should at once find that the number of vibrations was just twice as great as before; in

other words, that the octave vibrates with twice the rapidity of its fundamental. Likewise we should find that the fifth above the given fundamental note vibrates three times while the fundamental vibrates once, and so on. But we should also find that if we divide the first given string exactly at one-half of its length it will produce the octave above. Now we know that the octave above a given fundamental is produced by twice the number of vibrations in the same time as are required for the fundamental. Thus we arrive at the second great law of the acoustics of musical strings:

The pitch of any given string varies inversely as the length of the string—the shorter the string, the higher the pitch.

This law was first announced by Pythagoras, the Greek pre-Christian philosopher, and confirmed by the labors of Father Mersenne, the distinguished ecclesiastic and scientist of the seventeenth century.

As is well known to all students of acoustics, musical strings, when producing musical tones, must be stretched at some relatively considerable tension. It does not require much observation to discern the truth that the tension at which a string

is stretched must have some influence upon its frequency of vibration. For, exactly speaking, the application of greater tension to a string which has been at less tension is simply more or less of a de-flexing of the string, and vice versa. The pitch of strings does indeed also depend upon the tension at which they are stretched, and the rule in regard to this phenomenon makes the third in the series that is so important in our investigations. We state it as follows:

The pitch of a given musical string varies as the square root of its tension. That is to say, that if a string is stretched with a tension exerted by a weight of ten pounds, it will yield the octave above its original pitch when the weight is increased to four hundred pounds.

Another law of the same kind refers to the thickness of strings and states that—

The pitch of a given musical string varies inversely as its thickness. The thicker the string, the lower the pitch.

Lastly we note that—

The pitch of a given musical string varies inversely as the square root of its density. Thus a string of which the density is four times that of

another will have one-half the frequency of, and one octave lower pitch than the second string.

The laws laid down above are not correct absolutely when we are dealing with strings of less than ideal construction. The ideal musical string will be of perfect uniformity and perfect flexibility. Of course, it is not possible to make strings which will come within these requirements. However, the differences are slight, and for other than scientific purposes negligible.

CHAPTER II.

THE MUSICAL SCALE.

It is not necessary for us to go much into detail in considering the origin of the musical scale. Suffice it to say that the present diatonic scale of tones was first named and defined by Guido of Arezzo in the eleventh century. As is well known, this scale of tones forms the foundation of music, and upon it the design of all musical instruments is necessarily based. It consists of seven tones named after the first seven letters of the alphabet, and an eighth, which is the octave to, and named after the first.

The frequencies of the various tones of this scale have been carefully ascertained, and we are able therefore to observe that each and every degree of this scale bears a direct ratio to every other. Taking the frequency of the first note of the scale as unity, we find that the others bear the following proportions to it:

C	D	E	F	G	A	B	C
1	$9/8$	$5/4$	$4/3$	$3/2$	$5/3$	$15/8$	2

Let us proceed to examine the relations of these degrees to each other. Taking the proportions

mentioned above, we divide each pair of these, one by the other, and thus obtain the ratios of each degree to the next. Thus we are able to note the proportionate intervals that separate the scale degrees, one from the other.

Proportionate intervals between scale degrees:

C	D	E	F	G	A	B	C
9/8	10/9	16/15	9/8	10/9	9/8	16/15	

Close examination of the second of these two analyses will show that there are just three different interval proportions represented. They are distinguished by the three different ratios 9/8, 10/9, and 16/15. The first of these is slightly greater than the second, and either is considerably greater than the third. Now it is obvious that since the ratio between the first and second degrees of the scale is 9/8, and between the second and third 10/9, the interval is greater in the first case than in the second. In other words, the so-called "whole tone" or "whole step" between C and D is greater than the similarly denominated interval between D and E. The same discrepancy appears when the other degrees are compared. The semitone intervals between E and F, and B and C, are naturally a good deal smaller than the others. So that we see there are three kinds of

interval to be observed in a comparison of adjacent degrees of the diatonic scale. Ordinarily we have become accustomed to recognize merely the tone and semitone; we now see that the tone may be of two kinds. These two whole step intervals are denominated, respectively, the major tone and minor tone, and the other is called the diatonic semitone. And since the degrees of any diatonic scale must always appear in the same order, we now begin to see where some of the difficulties of our problem lie. For it is evident that, if we merely have the one scale of sound-producing bodies tuned so as to produce intervals according with one given base note and continuing in that relation throughout the compass of the instrument, it will be impossible to use that given scale of sonorous bodies, *in the one fixed tuning*, for any other tonality save only that of which the given basic tone is the keynote or tonic. For if we begin our tonality with any other note we at once disturb the fixed order of the diatonic scale and throw every interval and chord out of tune. For example, if the above given tonality be chosen as the basis of our tuning, and if we wish to play in a scale whereof the tone D, as given above, is tonic, we at once see that the first degree of this new

tonality is separated by the interval of a minor tone from the second degree thereof, while we know that the interval between these should be that of a major tone. Similar confusion must naturally exist everywhere, so long as the tones of any given scale are fixedly tuned in pure and true intonation.

So that we are reduced to the necessity either of having a different set of sound-producing apparatus for every tonality in which we may want to play, or else of manipulating the interval proportions in such a way as to extinguish the difference between the whole step intervals.

Again, another difficulty presents itself. Music cannot satisfactorily express all its moods and thoughts through the medium of a pure diatonic scale. It has long since been found necessary to interpolate other sounds between the whole steps. These sounds have become known as "chromatic semitones." They are obtained by taking the difference between a minor tone and a diatonic semitone (as by dividing the ratio of one by the ratio of the other), and the appropriate ratio of the interval thus formed is found to be $25/24$. Now if we consider the C of the scales above given to have a frequency of 512 vibrations per second (the

pitch generally used for convenience in calculation, as it is the ninth power of 2), we find that the frequencies of a diatonic scale thus calculated will be:

Names of degrees...	C	D	E	F	G	A	B	C
		9	5	4	3	5	15	2
Ratio, each to C....	1	$\frac{9}{8}$	$\frac{5}{4}$	$\frac{4}{3}$	$\frac{3}{2}$	$\frac{5}{3}$	$\frac{15}{8}$	$\frac{2}{1}$
Internal proportions..		$\frac{9}{8}$	$\frac{10}{9}$	$\frac{16}{15}$	$\frac{9}{8}$	$\frac{10}{9}$	$\frac{9}{8}$	$\frac{16}{15}$

		Major tone	Minor tone	Diatonic semitone	Major tone	Minor tone	Major tone	Diatonic semitone
Frequencies...	512	576	640	683.2	768	853.2	960	1024
	C	D	E	F	G	A	B	C

Now a chromatic semitone may readily be obtained to any of the degrees above calculated. The process is to divide or multiply by the difference between the intervals of a minor tone and a diatonic semitone; namely, by the ratio $25/24$. So that the chromatic semitone above C 512 will be C-sharp $512 \times 25/24$, or 533.333 plus. The chromatic semitone below the adjacent D will be D-flat $576 \div 25/24$, or 552.96. This shows that D-flat,

contrary to supposition, is higher in pitch than C-sharp.

Now, knowing the frequency of C-sharp according to the above given scale of C, let us note it in a scale of which the tonic is D (the major second of the scale of C). In this latter case the sound, C-sharp, is the major seventh of the scale of D. This tonic D being the major second of the scale C, will have a frequency of 576, so that the frequency of C-sharp, its major seventh, in that scale, will be $576 \times 15/8$, or 1,080. But this C-sharp will be the octave above the C-sharp which is the chromatic semitone above C in the scale of C. Therefore, the frequency of the octave below it, or the latter C, should be one-half of 1,080, or 540. Our calculations, however, have shown that the frequency of the chromatic semitone above C (C-sharp) is 533.333 plus. Thus we see that the chromatic semitones, as well as the diatonic scale degrees, differ, in pure intonation, according to the variation of the tonic of the scales of which they form a part.

These simple illustrations serve to show in a very clear manner that the requirements of pure intonation are beyond the capacity of keyed musical instruments, constructed according to pres-

ent methods. For it is obvious that the pitch of every sound within the compass of a pure intonation instrument must be slightly changed whenever it is desired to modulate from one tonality into another. And this change, slight as it usually is, involves mechanical problems so serious, and constructional modifications so revolutionary, that they have never been carried out except in certain experimental instruments chiefly designed for laboratory work. In this connection the experiments of Helmholtz, Ellis, Zahm and Hagaman are worthy of notice.

Seeing that the piano, as well as other keyed instruments, is at present built to be operated with fixed tones, it is clear that the required modifications outlined above cannot be made. The necessity is therefore apparent for some system of compromise, whereby the tuning of the instrument may be adjusted to its mechanical limitations. It is at this point that we approach the real crux of our problem; the questions relating to what is known as temperament.

From time to time, as the art of music developed, the necessity for a compromise of the character outlined above has been recognized by musicians. Even where scales other than the diatonic

have formed the basis of music, it has been found that similar difficulties of intonation have arisen, so that from earliest times systems of tempering the intervals of the scale have been invented.

Without going into elaborate detail, let us proceed to consider at once the system of temperament which is now universally practiced. It is known as the "Equal Temperament," and its invention has been ascribed to J. S. Bach, although it certainly seems to have been known, theoretically at least, long before his time. Let us say at once that the "Equal Temperament" possesses obvious advantages, and glaring disadvantages. It is simple, easily understood, and very convenient. It divides the octave into equidistant semitones, and abolishes the differences between major and minor tones, and diatonic and chromatic semitones. It reduces the whole octave to a set of thirteen semitones, equally distant from each other. Thus it permits an absolutely untrammelled freedom of modulation, and a consequent extraordinary latitude in musical composition.

Its disadvantages are not less clear. It deprives us at once of the delicate and subtle differences between consonant and dissonant chords; it reduces all chords and intervals to a uniform

harshness and roughness, and is confessedly, in fact, a compromise with difficulties that have hitherto been insoluble, rather than the last word in musical intonation.

CHAPTER III.

THE EQUAL TEMPERAMENT.

In spite, however, of the disadvantages that we so justly ascribed to the equal temperament, it is useless, as things now are, to consider any other system of intonation. Until mechanical ingenuity has supplied the instruments, and composers have arranged the modulations, for the performance of music in pure intonation, we must perforce be contented with the Equal Temperament. It therefore remains to investigate its application to the practical work of tuning the piano.

As a matter of comparison, there is appended herewith a table showing the pure modern diatonic-chromatic scale contrasted with an equivalent scale in equal temperament. In each case the frequency is calculated from C 512 and the figures are taken on the authority of the Rev. Father Zahm, one of the most eminent of modern acousticians, and author of that beautiful classic "Sound and Music."

Modern Pure Diatonic-Chromatic Scale.		Equivalent Equal Tempered Scale.	
512	C	512	
533.4.....C-sharp.		C-sharp—D-flat	542.4
552.....D-flat.			
576	D	574.6	
600.....D-sharp		D-sharp—E-flat	608.8
614.....E-flat			
640	E	645	
682.6.....F			683.4
711.....F-sharp.		F-sharp—G-flat	724
737.2.....G-flat.			
768	G	767.2	
800.....G-sharp.		G-sharp—A-flat	812.8
819.2.....A-flat.			
853.4.....A			861
888.8.....A-sharp.		A-sharp—B-flat	912.2
922.....B-flat.			
960	B	966.4	
1024	C	1024	

Even a cursory study of the above table will indicate the manner in which the degrees of the diatonic-chromatic scale are distorted for the purposes of temperament. Accepting these figures, let us now pass at once to the consideration of means for practically applying them to the work of tuning.

It will be observed that the only degrees of the octave of tempered sounds which remain pure are the first and eighth. In other words, every interval except that of the octave is, in the tempered scale, more or less impure. The degree of impurity is greater in the case of the seconds, thirds, sixths and sevenths, and less in the fourths and

fifths. It remains for us to discover some method whereby we may proceed without serious difficulty to the task of estimating the actual impurities permissible in each case.

It is obvious that even if we know exactly by how many vibrations per second each degree of the tempered scale must be altered at any given pitch, there still remains the difficulty of estimating these proportional impurities while tuning. The work of tuning is performed fundamentally by means of aural perception. Is there any way in which we can guide our auditory faculties so that we may at once cognize any required impurity? The answer, fortunately, is in the affirmative. Such a way does exist, and presents, indeed, a very sure and accurate means for estimating these slight and elusive differences. In order to appreciate it, however, we must digress for a few moments, and hark back to our acoustical researches.

BEATS.

The student of acoustics is familiar with the phenomena of interference; that is to say, with the singular results that are observed to ensue from the simultaneous projection of sonorous

waves which have different phases. In such cases, as when two sonorous waves of a similar frequency, generated by two sounding bodies, bear to each other such relations that the condensation of one wave synchronizes with the rarefaction of the other, the crest of one wave will synchronize with the trough of the other, and the two waves will therefore cancel one another, and complete extinction of sound will result.

There is another class of sounds, which, however, are more frequently encountered; namely, sounds which are not quite in unison with one another. When two sounds not completely in unison are simultaneously excited, instead of being extinguished, they give rise to certain peculiar phenomena denominated "beats." These "beats" are easily recognizable and form criteria for very accurate estimation of minute differences in frequency. Obviously then, if we can learn what beats are and how to recognize them, we can at once see how it may be possible to arrive at most accurate determinations of minute frequency differences, such as are considered in tuning intervals in equal temperament.

We know that sounds are at the same pitch when they are generated by sonorous bodies hav-

ing the same speed of vibration, and it is easy to perceive that, if two such bodies are sounding together, the condensations and rarefactions of the layers of air will synchronize with each other, so that both will be exciting condensations at the same instant and likewise will generate rarefactions simultaneously. And even if the two bodies have not exactly the same speed, the result will be equally simple as long as their speeds bear simple ratios to each other. Thus two bodies which are emitting sounds at the interval of a fifth or a fourth will generate condensations and rarefaction in such a manner that they will not interfere one with another. But the case is different where two sounds are separated by differences in pitch that cannot be expressed by simple ratios. For example, if one sound be one vibration per second higher in frequency than another, it is clear that by the time the first sounding body has completed its given number of vibrations, the other will be one vibration behind. When, therefore, the vibrations of the first body are continued into the next second, the condensation of one wave will be completely synchronous neither with the condensation nor the rarefaction of the other. In the first case we have a considerable augmentation of sound

and in the other case a complete silence. As the waves thus approach and recede there is a gradual diminution of sound followed by a complete cessation for a fraction of a second, and then a gradual increase until the point of greatest augmentation is reached. This latter happens when the two condensations concur, and the gradual rise and fall of the sound correspond to the gradual approach of this concurrence in the first place and to the similar advance of the point of crossing in the second. This phenomenon of alternate augmentation and diminution of sound separated by an almost inappreciable interval of silence occurs whenever two sounds of nearly the same pitch are heard simultaneously. These peculiar changes in the intensity of a sound are denominated "beats."

This description of the physical nature of "beats" will be sufficient to make clear to us how a recognition of them is of value to the tuner. From what we have just said it will be observed that the number of beats that may be set up between any two sounds depends upon the difference in their frequency of the two sonorous bodies. So that the number of beats forms a true guide to the exact amount of difference between sounds

that are nearly in consonance. Thus, if it becomes a matter of tuning a certain interval a little flat or sharp in order to comply with the requirements of Equal Temperament, the operation may be readily performed by observing the number of beats that are heard between the two sounds when one of them is sharpened or flattened. So that all schemes of tuning must necessarily be founded upon a recognition of this important phenomenon.

The above is quoted from the fourteenth chapter of "Theory and Practice of Pianoforte Building," since it gives a description of the physical nature and practical utility of beats, which I can hardly improve upon for the purposes of the present treatise.

CHAPTER IV.

PRACTICAL APPLICATION OF THE EQUAL TEMPERAMENT.

In the last chapter we discussed the acoustical and musical significance of the Equal Temperament and its influence upon the intonation of the musical scale. We also devoted some space to consideration of the phenomena of beats, and demonstrated their essential importance and indispensableness as guides in the work of tempering musical sounds. From what was then said, it will be apparent that the work of applying the principles of Equal Temperament to the work of piano tuning will be accomplished when we know, first, how much difference there is to be between the true sounds and their tempered equivalents; and, second, when we can use the beats set up between the slightly disturbed interval members as guides for determining the correct proportion of disturbance.

While the pitch of the scales already given is calculated from the acoustical C 512 rather than from the musical C 517.3, there will be no diffi-

culty in applying our information to the case of the latter, which is generally used to-day under the name of "International Pitch" for tuning pianos and other musical instruments. Let us proceed to do so.

Suppose that we tune an ascending major third interval from any given tonic, and that we then build another major third upon the first and a third similar interval upon the second one. The distance between the original sound and the last one so obtained will be one octave. It will, however, be found that the octave thus built up from the original tonic will be flatter than the octave directly obtained by doubling the frequency of the original tonic.

Again, if we build up a series of four consecutive minor thirds in the same way, we shall also obtain an octave, and again it will be found that such octave very considerably differs from the octave obtained direct from the original tonic. In this case the direct octave is flatter.

A similar result is obtained by building up twelve consecutive fifths. Such a progression extends to exactly seven octaves, and yet the last tone so obtained differs considerably from the tone produced by the building of seven octaves

upon one another, the former being sharper. Avoiding tedious calculations, we may express the exact results of these comparisons in the following manner:

Octave generated by	Octave generated directly from			
3 major thirds	: tonic. =	125	:	128
4 minor thirds.	: tonic. =	1,296	:	1,250
12 perfect fifths	: tonic. =	531,441	:	524,288
(seven octaves)	(seven octaves)			

Understanding all this, we at once see that, in order to obtain the interchangeable features of the Equal Temperament, we must tune the various intervals mentioned above sharp or flat, in accordance with these ratios. Thus, we see that each of the four minor thirds in the octave is too sharp and so must be tuned flat by one-fourth of the ratio of 1250:1296. Each of the three major thirds likewise must be sharpened by one-third of the ratio 128:125. Each of the fifths likewise must be tuned flat by one-twelfth of the ratio 524288:531441.

How shall we aurally estimate the proportions stated above in such elaborate figures? The method is simple. Taking the researches of Helmholtz as a guide, we find that he calculates that the mean difference between the two sounds

constituting a tempered fifth should be such as to generate between them 0.6 of one beat per second in the octave around middle C at the international pitch. That is to say that at standard pitch (517.3 C), there should be an average approximation of 3 beats in 5 seconds between the sounds that constitute perfect fifths within that octave. Now it is obviously impracticable to attempt to hold the clock on beats in the manner suggested above, but if we do so tune these fifths as to obtain an average of two distinctly audible beats before the sound dies away we shall obtain two beats in approximately three seconds, as against a similar number in three and one-third seconds; the latter being the actual rate as calculated by Helmholtz. In the same way we find that the tempering of fourths should produce an average of one beat per second, or three audible beats in three seconds, within the same octave. Let it here be noted that the beat-rates above mentioned are averages, and that the actual number of beats increases in an ascending direction; thus causing the intervals below middle C to beat more slowly than the average and those above more rapidly.

As we stated before, the fifths must be flatted

in order to satisfy the requirements of Equal Temperament. Therefore, we see that it is necessary to tune these intervals within the middle octave so that the upper sound of the fifth is flat of purity by two audible beats. Similarly, the upper sound of the fourths must be tuned so as to be sharp by three audible beats.

Of course, it is not the easiest thing in the world to estimate accurately the beat-rates of intervals that are so nearly pure as the fourths and fifths. But there are various tests that can be used to guide our work. For example, when we have fixed the pitch of middle C and are about to continue "laying the bearings" (that is, adjusting the temperament of one octave of sounds by fourths and fifths or otherwise), we first tune the F below middle C, then the G below middle C, and then the D above G. When we reach this last sound, we find that a new interval presents itself; the major sixth F-D. If the fifths already obtained are too flat the sixth will beat too slowly, and conversely will beat too fast if the opposite condition prevails. The major sixths should beat about nine per second, and the major thirds about eight in the same time. Now when we proceed to the

next sound after tuning D and tune D-A, we shall have a major third F-A. This gives us another test of the correctness of our work. In this way the work goes on until the whole octave of tempered sounds have been obtained.

It will be well to put in tabular form a statement of the method followed in "laying the bearings," together with the approximate beat-rates throughout. Let it be understood that tuners are pretty nearly agreed in tuning from middle C and the method of "laying the bearings" by fourths and fifths has the sanction of the most eminent exponents of the art. It is necessary to start the work of tuning by this plan of "laying the bearings" simply because it would be impracticable to attempt the tempering of every interval throughout the compass of the instrument, without reference to any other interval. In order to simplify things, we simply adjust one octave of sounds by careful estimation of the beat-rates and then proceed to tune all the others from this one by octaves.

The method of laying the bearings then may be described as follows:

1. Tune pitch C by tuning fork.

2. Tune pitch F below C, a fifth, so that F is a little less than two audible beats sharp (or C two beats flat).

3. Tune pitch G below C, a fourth, so that G is a little less than three audible beats flat.

4. Tune pitch D above G, a fifth, so that D is two beats flat. Test the sixth F-D, seeing that it gives a correct beat-rate.

5. Tune A below D, a fourth, so that A is a little less than three audible beats flat. Test the third F-A and the triad, F-A-C.

6. Tune E above A, a fifth, so that E is flat by two beats. Test the third C-E and the chords A-C-E and G-C-E.

7. Tune the B below E, a fourth, so that B is flat by a little less than three audible beats. Test the third G-B, and the chord G-B-D.

8. Tune F-sharp below B, a fourth, so that F-sharp is flat by a little less than three audible beats. Test the chord F-sharp-A-D.

9. Tune C-sharp above F-sharp, a fifth, so that C-sharp is two beats flat. Test the third C-sharp-A and the chords F-sharp-A-C-sharp and A-C-sharp-E.

10. Tune G-sharp below C-sharp, a fourth, so that G-sharp is a little less than three audible

beats flat. Test the third G-sharp-C and the chord G-sharp-B-E.

11. Tune D-sharp above G-sharp, a fifth, so that D-sharp is two beats flat. Test the third D-sharp-B and the chords F-sharp-A-D-sharp and G-sharp-B-D-sharp.

12. Tune A-sharp below D-sharp, a fourth, so that A-sharp is a little less than three audible beats flat. Test the thirds A-sharp-F-sharp, A-sharp-D, and the chord F-A-sharp-D.

13. Tune F' above A-sharp, a fifth, so that F' is flat by two beats. Test the octave F-F' and the chord G-sharp-C-sharp-F'. This last F' is the octave of the first F' tuned and should coincide exactly with it, the coincidence being determined by the entire absence of beats.

After the bearings have been laid in this manner the work is continued in either direction by octaves.

The practical handling of the tuning hammer and the methods to be adopted to accustom the ear to the estimation of beats will be the subjects of the next chapter.

UNISON TUNING.

It now becomes necessary to consider the matter of tuning the various intervals in a practical

manner. We shall begin with a consideration of unison tuning; that is to say, of the actual work of bringing the three strings of a string-group into exact tune with one another.

CHAPTER V.

UNISON AND OCTAVE TUNING.

The statements made in earlier chapters relative to the phenomena of beats and their influence upon the science and art of piano tuning must have made it already abundantly clear how profoundly they affect every part of the work. The whole art of tuning rests, ultimately, upon observation and comparison of the phenomena indicated by disturbed unisons. For the unison is the first and simplest interval and the easiest manner of observing the operation of beat-phenomena is found in connection with it. In fact it is considerably easier to detect the existence of beats between two sounds that are nearly in *unison* than between two sounds that are merely almost in *consonance*. In other words, it is not so difficult to detect and count the beats between two strings of the same unison group on a piano as to undertake the same task with strings that are separated in pitch by the intervals of, say, a fourth or a fifth.

We have already discussed the physical nature of beats, and have also made some statements regarding their audible manifestations. It now remains to apply this knowledge practically, to note how we may train the ear to hear them, and to discover just in what manner they may be useful to us in the prosecution of our work.

We are amply justified in beginning the discussion of practical tuning work with a description of the methods used in adjusting the pitch of unison strings. As said above, unison tuning is the foundation of the whole art. Not less is the unison itself the foundation of the musical progression of tones. When we have learned just how to go about the work of tuning the strings of a unison we shall also practically have learned how to perform the same operation with reference to the octave, and later the other intervals in their proper order.

Let the student approach a piano armed with tuning hammer and wedges. Let him uncover the tuning pins by removing the music desk. Then let him place his hammer upon one of the pins and also wedge up one of the strings of the corresponding unison group. In this way the wedged-up string is stopped from speaking and

the unison group is reduced to two strings, one of which is connected with the pin upon which the hammer has been placed. Assuming that these two strings are exactly in unison (and if they are not, they should be made so by a professional tuner before the experiment is begun), turn the hammer slightly to the left (away from the body when the right hand is on the hammer). This will flatten the pitch of the string by slackening its tension. Then listen attentively to the sound which ensues when the corresponding key is struck. At once one will observe a confused jangling and howling, much the same as is heard when a cracked church bell is sounded from a steeple. Observe carefully the nature of this confused jangle. It consists of a continual alternate rising and falling, ebb and flow, of sound, where the two contesting elements generated by the two non-unisonal strings seem each to be alternately the victor and the vanquished in the contest.

Let the hammer now be gradually moved back in the opposite direction, so that the disturbed string gradually reapproaches the unisonal state. The first change in the sound is at once perceived in the slackening of the rate at which these ris-

ings and fallings succeed each other; in a lengthening, that is to say, of their period. As the hammer is still further turned, the risings and fallings, which already we discern as those "beats" whose nature we have discussed, become less and less frequent, until at last they merge entirely into the unisonal sound and vanish. When this state of affairs is reached, the unison is again perfect and the two strings exactly in tune one with another.

The above explanation, if carefully read and digested, will provide a certain means for detecting the presence or absence of beats. Inasmuch as we are to gauge the excellence of our tuning work by just such means, the importance of training the ear to observe and discern these phenomena will be admitted without discussion. The student undoubtedly ought to devote considerable time to the work of correcting disturbed unisons, and for the present he will be doing enough if he merely gets his strings in and out of tune without much regard for a professional method of handling the hammer. When he has mastered the art of detecting the beats in a disturbed unison he may consider the application of his knowledge to the matter of octave tuning. The pro-

cedure is essentially the same, and the two sounds will be found to merge into one another just as do the two or three sounds of a unison. The beats will occur in precisely the same manner and their number will be the same as in similar unisonal cases. The student will require, however, a somewhat longer time to detect the beats in this interval, and when detected it will be a little less easy to perceive when they entirely disappear. Particular care should therefore be taken in this matter and the student must not consider himself proficient in the matter of unison and octave tuning until he has assured himself of his ability successfully to adjust these intervals in all parts of the piano. Considerable difficulty will be manifest in certain parts of the compass, particularly in the low bass, but patience and perseverance will enable the learner to prevail at last. Practice with double octaves as tests will be found very helpful.

When practical work is taken up in earnest, there will be found the want of an authoritative test for the correctness of octave tuning. Mere reliance upon the detection of beats between the extreme sounds of the octave cannot uniformly be depended upon, especially in the lower bass

and in certain parts of the high treble. It is therefore necessary to seek a test that shall be as reliable as and more easily applied than this.

The minor third above any given tone is the same sound as the major sixth below the upper octave to the given tone. If the beats existing between the given tone and its upper minor third are exactly equal to the beats between the upper octave and its lower major sixth, then the given tone and its octave are exactly in tune. In other words, if we are tuning F-F¹, we test the beats between F and A-flat, and if we see them to be exactly equal in number to the beats between A-flat and F¹, then we know that the octave is exactly correct.

The reason for this, and the foundation for the assumption of its correctness as a test, lies in the fact that there are partial tones pertaining to each of these three sounds, which are equivalent in name but non-unisonal, the latter peculiarity being traceable to the disturbing influence of the equal temperament.

Thus the sixth partial tone of F and the fifth partial tone of A-flat will alike be C³. So also will be the third partial tone of F¹. The beats between F-A¹ and A¹-F are generated by the

disturbed C3 unison, this sound differing in pitch according to its position in one or other of the original sounds. The disturbance of unison is, of course, due to the process of temperament.

Another test for the correctness of octave tuning is found in the major under-thirds and tenths. In the same case F-F1, the beats between F-C-sharp, a major under-third, are compared with those between C-sharp-F1, a tenth. In this case also the beats on each side must be equal to assure correctness of pitch. The cause of beats in this case is precisely similar, of course, to that which has already been described.

It will be observed, as is naturally of course the case, that the beats between such intervals increase in number as the frequency of the sounds increases. The beats will therefore increase in number as the pitch of the sound rises, so that there are more beats between sounds in the treble than in the bass, and conversely.

When tuning the lower bass tones, the young tuner will find a great deal of difficulty at first. It is indeed very difficult to discern the true beats generated by the clashing of non-unisonal sounds in this register, and to differentiate between them and such as are inherent and produced by defects

of the strings themselves. Long practice, a delicate ear, and much patience are required before these perplexing sound problems can be solved with correctness. The hints already given will be of much value in assisting the student towards a better comprehension of these problems. And such comprehension, when complete, is the first step towards solution.

One of the most frequent causes of trouble in connection with the tuning of unison strings is found in the false beats oftentimes generated therein. Faulty drawing of the wire, careless twisting during process of stringing, incorrect tension due to mistakes in scale drawing; all these causes operate to produce false beats in strings. In such cases the sound given out by a single string, instead of being pure and smooth, is disfigured by the presence of beats, which are liable to cause great confusion whenever two strings are to be tuned together. Sometimes this condition of affairs is so serious that it renders smooth unison tuning quite impossible.

When this kind of thing exists it is better to compromise with the evil than directly to assault it. In some cases an approximate unisonisation may be brought about by slightly sharpening or flat-

ting the other strings of the group, so that one set of beats may, as it were, neutralize the other. Care, attention, practice, and refinement of the auditory powers will render such tasks continually less difficult.

A question that has been much agitated pro and con has to do with the prevalent custom of tuning the higher treble tones purposely too sharp. Theoretically, such a course is entirely indefensible, and if everyone possessed perfect appreciation of pitch, there would be no demand for what is really a corruption. Unfortunately, however, almost all ears tend to hear very high tones as flatter than they really are. Hence, unquestionably, the feeling that accurately tuned octaves in the highest portions of the compass are flat. It is to overcome this almost universal tendency that tuners have agreed in tuning the highest octave and a half or so of tones somewhat sharp.

The principal trouble with this practice is that there exists no standard whereby the exact appropriate proportion of sharpening may be ascertained and applied. Hence it is necessary to rely entirely upon the individual judgment of the tuner; by no means an ideal method. Personal experience has

suggested the following observations, which the student may profitably apply:

Let each and every tone of the higher registers be tuned at first with as much exactitude as is at command. Then let the pitch be sharpened just enough to make the change perceptible. Let a careful watch be kept, lest the degree of sharpening increase gradually toward the upper end of the scale. Test particularly the tones from the highest A upwards. It will frequently be found that the pitch of the B has been sharpened until it forms a true octave to the C below. Such mistakes must be detected and remedied.

TUNING OF OTHER INTERVALS.

We have already discussed quite fully the results that must be obtained in order to "lay the bearings" in Equal Temperament. We may now go a step further and consider practically how to manage our tuning so as to obtain these results with other intervals.

It will at once be found, upon testing, that beats between the members of fourth and fifth intervals are less easily recognized than when they occur in an octave. Nevertheless this is a matter which practice will quickly adjust. Quite on the

contrary, it will be found that in the case of thirds and sixths their beats are very distinctly heard, and the only chance of confusion lies in the great rapidity with which they are produced. Inasmuch as we base our tuning scheme upon fourths and fifths, and use the other intervals for comparison and test, we must consider the matter of tuning the former with due regard to the peculiarities of the Equal Temperament. As will be remembered, it is required to obtain an average of approximately two distinct beats in the fifths, and three in the fourths, within the middle octave. The beats generated in these intervals are naturally alike, whether the note tuned is sharp or flat of the other. This makes it difficult sometimes to know whether one is on the sharp or flat side. In order to reduce the chances of error here it is well first to tune the interval perfect and then to depress or raise the pitch until the required number of audible beats are heard.

It has already been stated that tests of the correctness of fourth and fifth tuning are made by comparison of the thirds and sixths as the work goes on. Although it has been possible to state the number of beats that these latter should give out and to be sure of the correctness of

such statements, yet it is almost impossible to estimate these beats numerically by the unaided ear. Nothing but practice can enable one to determine instinctively when a third or sixth is quite correct. Of course, such a result follows naturally when the work on the fourths and fifths is also free from fault, but inasmuch as the thirds and sixths are used to check the correctness of the others it is necessary to be well acquainted with their proper beat-rates. As before said, however, this can only be well done after much practice and experience. Until the beginner has had some practical work, therefore, the hints already given must suffice.

MANIPULATION OF THE TUNING HAMMER.

We have here a problem that has been attacked from many sides, and to which the answers are numerous and conflicting. Every tuner sooner or later develops a peculiar style of holding his tuning hammer, and an individual manner of turning the pins with it. Although it is not part of our present intention to dogmatize on this subject, there are a few hints that should be given and followed, if a proper style is to be acquired from the first.

Let it be remembered, in the first place, that the pins of an upright piano tend constantly to lean forward and downward, under the pressure of the strings. Such a state of affairs, however, is bad, and manufacturers adopt various expedients to retard this inevitable sagging. The pins are driven into the wrestplank with their heads inclined upward. Wooden collars are fitted tightly around them where they pass through the holes in a full iron plate; these and other methods are in use. None of the ordinary causes which operate to produce sagging of the pins, however, is so common and disastrous as improper handling of the tuning hammer. All the tuner's efforts should be directed towards the development of a style that will enable him to turn the pins without either bending or wrenching them. In order to accomplish this it is absolutely necessary to hold the hammer as nearly as possible in a vertical position; a requirement which eliminates the sitting position. Moreover, the hammer must not be dragged downwards so as to pull the pin down with it.

The ideal method of turning the pin is to bring the hammer into close engagement with it and then gently to work the former forward and back by a muscular movement of the arm, using no

force on the backward movement, but pressing with gentle, steady force at each forward movement. In this way the extremity of the hammer-handle will be moving back and forth in the arc of a circle, of which the chord will measure about half an inch in length. This nervous muscular movement will drive the pin steadily backward or forward, according to the direction in which pressure is applied, without doing any harm to the wrestplank.

Inasmuch as the strings on the upright piano descend to the bridge on the side of the pin nearer the bass, the tuning hammer will incline to the opposite side of the pin when used in the right hand. Although careful handling will eliminate most of the disadvantage consequent on this position, the fact remains that the left hand should be used when tuning the upright. For when the hammer is used in the right hand the act of raising the pitch tends to drag the pin downwards. In the other case the tendency is to push the hammer upwards when the string is sharpened, thus assisting instead of retarding its progress.

These observations do not apply generally to the grand piano, although the position of the upper treble pins, in close proximity to the sides of the

piano case, makes a left-hand position advantageous for these. Generally, however, the right-hand position is better on the grand.

CHAPTER VI.

ON THE USE AND ABUSE OF TOOLS.

The first and most important of the tuner's tools is, of course, the tuning hammer. We have already had something to say concerning the manipulation of this instrument, and it now remains to discuss it from another point of view.

In the first place, let us consider the form and nature of the tuning hammer. As made to-day, it usually consists of a long, hollow handle, having an extensible steel shaft concealed in it, which latter can be pulled out so as practically to double the effective length of the handle. On a thread tapped in the end of the shaft is screwed the hammer head. This important part of the instrument is provided with an orifice shaped to permit engagement with the tuning-pin. For use on square pianos, these heads are made with oblong apertures; for uprights and grands the holes are cut either square or star-shaped. When one buys a head of the oblong variety, it is better to get the double kind; that is, a head provided with two

shafts and having the holes cut at different angles. By this means one is able to adjust the hammer on the pin in a convenient manner always.

The star-head will be found a great deal more convenient than any other kind for work on grands and uprights. This is owing to the fact that with it one can always adjust the hammer to the pin conveniently, without the necessity of continually turning from one side of the head to the other.

The student of the tuner's art, when first he gets a tuning hammer in his hand, is likely to fall at once into bad habits, and all unwittingly to wreak varied and diverse sorts of destruction upon the pianos which he is permitted to use for experimental purposes. For the proper manipulation of the hammer is a delicate and difficult thing, which must be approached in a patient and determined manner.

As was stated before, one of the most important problems to be considered in connection with this matter has reference to turning the pins without also bending them. In the upright piano the position of the pins is such that this bending inevitably results from an improper hammer-position. Hence the student must try to acquire a correct style from the start, so that bad habits may not

grow upon him unconsciously, to become ever-increasing obstacles to his success.

Most essential of all is the position of the hammer, with reference to the plane of the string. If the hammer be so adjusted that it leans toward the left-hand side as one faces the piano, then the operation of tightening the string will tend to lift the pin up instead of pulling it down, and thus will tend to support it while it is being turned. In this way the danger of bending is almost entirely avoided. But a position like this is very awkward when the right hand is used on the hammer. Hence one must become accustomed to using the left hand when tuning upright pianos. This seems to be difficult advice, but it is surprising how soon one becomes accustomed to the left-hand position.

For precisely similar reasons, of course, the right hand should be used on the grand. Even here, however, the tuning of the upper treble register is greatly facilitated by the use of the left hand. With the square piano, again, conditions are the same as with the upright.

The hammer must always be held in a position as nearly vertical as possible. This will involve continual standing on the part of the tuner, but this is no great hardship. The sitting position

encourages slovenliness of work and careless methods generally, leading to bent pins, wrenched wrestplanks and innumerable other evils.

When the angle made by the hammer with the floor is a right angle, then the hammer is in the best possible position. For, thus placed, it is difficult not to turn the pin correctly, whereas this difficulty runs more and more the other way as the angle of the hammer with the floor becomes more and more acute.

Of the other tools which the piano tuner must always have with him, a reliable tuning-fork is most necessary and essential. In these days, when some sort of an attempt is being made to maintain the standard international pitch, it is absolutely essential to possess a tuning-fork guaranteed to give 435 vibrations per second for A, or 517.3 per second for C. Such forks can be obtained at a moderate cost from piano supply houses.

Next in importance we must consider the provision of suitable wedges. It is customary to use long wedges made of rubber or felt for stopping off the strings in the middle and lower registers of the upright piano, while for the higher treble it is the custom to use a long, narrow stick of wood pointed at one end, and with the pointed end cov-

ered with felt. This is generally known as a stick-wedge and it is necessary to use it in the upper portion of the upright piano, on account of the fact that the hammers in that part strike so close to the upper bridge that there is no room to insert the ordinary rubber or felt wedges.

Practice differs greatly as regards the use of these necessary instruments. Some tuners, when laying the bearings, are accustomed to use a set of thirteen rubber wedges, so as to stop off all but the middle string of each string group in the octave. One advantage of this method lies in the fact that it is thus possible to make any necessary modifications in the pitch of any tone within the octave after the bearings have been laid once, and yet to do so without disturbing more than one single string on each group. When the bearings have been satisfactorily laid and tested in this manner, the remaining members of the groups can be adjusted at leisure. It cannot be denied that this method has many advantages for the student, inasmuch as he is certain to require very frequent modifications and tests while learning the art of laying the bearings. The seasoned tuner, on the other hand, doubtless gets along well

enough with fewer wedges, but such a course is not to be recommended to the beginner.

We now have to consider another of the tuner's instruments which is exceedingly important. I refer to the felt picking needles. But before we consider the use of these valuable aids it is necessary for us to discuss at some little length the scientific basis of the art of voicing the piano.

CHAPTER VII.

VOICING.

Everybody knows that when we pick the felt hammer of the piano we modify the quality or color of the tone elicited from the string. The scientific reason for this, however, is not so generally understood, although it is susceptible of a very simple explanation.

When the head of the hammer is very hard, and the felt very tightly compressed, its rebound from the string is instantaneous. On the contrary, if the head be soft—that is, relatively soft—it will be found that the rebound is delayed for a minute fraction of a second on account of the tendency of the soft felt to cling slightly to the string. Of course, the difference between the elapsed times of rebound in the two cases is not perceptible to the eye. Yet it exists and has very important results.

This very slight tendency to cling to the string which is exhibited by the relatively soft hammer has the effect of damping off the partial tones which are generated around the nodal point at which the hammer strikes. It has already been explained that the upper partials of a vibrating

string are necessarily more or less dissonant. The proportion of dissonance increases with the remoteness of the partial. Hence, inasmuch as the hammer strikes a string at a point between one-eighth to one-tenth of its length, according to its position in the scale, the partial tones which are most likely affected by the stroke of the hammer are those high tones generated by segments of the string smaller than one-eighth of its length. Now, since the quality of the tone depends upon the prominence and intensity of its partials, it is obvious that such partials as we have been describing, being dissonant in their nature, must necessarily affect the color of the tone. When they are permitted to vibrate freely the color must necessarily be more or less harsh. In the same way when they are damped off the effect must be that of producing a more mellow, less harsh, and less metallic quality of tone.

This is the scientific explanation of the effect upon the piano of toning or voicing its hammers by means of the needles. Although this process has been in use ever since the production of felt covering for hammers, it is nevertheless true that many tone-regulators do not understand the physical basis of their work.

When we comprehend properly this physical basis of tone-regulating or voicing, we are able to understand much more clearly why certain methods of manipulating the needles will give better effects than other methods. It will be well for us to consider these methods somewhat carefully.

The tuner whose work lies outside of the factory is usually called upon to improve the tone of old pianos, not of new ones. Hence he is most frequently engaged in working with old and partly worn-out hammers. These, of course, demand particular treatment.

Before attempting to manipulate the felt of old hammers with the needles it is necessary to see whether they require to be sandpapered. This must always be done, in fact, when the hammers are very much cut into and flattened by their continual impact against the strings. It is impossible to make any good impression with the needles upon hammers that are badly knocked out of shape, and consequently in such cases one must resort to the use of the sandpaper file. This is a strip of wood about six inches long, preferably made from a cigar box cover and about one inch wide. Sandpaper is glued upon each side. When hammers are in a very much worn-down condition it is

necessary sometimes to use a coarse paper, such as No. 2. This can be smoothed and corrected later by the use of a fine paper on another file. For ordinary purposes, however, No. 1½ paper gives the best results.

Every effort should be made when filing the hammers to preserve their original shape. In other words, one should be careful not to file them so as to make the crown flat. This can be accomplished by filing from the back of the hammer towards the front, and from the top to the bottom sides separately, so as to bring the filing to a point at the crown of the hammer. In cases, however, where the hammers are so flattened that this cannot be done satisfactorily it is better to shape them up by the use of a small toy flatiron, heated to the same temperature as an ordinary flatiron, and with a damp cloth held tightly over the hammer to prevent it from being scorched and to give the advantage of the steaming that thus arises. The felt can be shrunk and shaped very neatly by this method, which, however, must be used with great discretion.

When the hammers of an old or worn piano, by any of the means already described, have been worked up into good conformation, the voicer pro-

ceeds to test the quality of tone produced from them. It will usually be found that this is of a harsh and metallic nature, due to the packing of the felt at the crown of the hammer. Such a condition must be remedied, but not until the tone quality has been well judged by both hard and soft strokes upon the strings. Very often it will happen that a hammer which gives a good tone when the key is lightly struck will be found to produce a much less agreeable quality when the blow is more forcible. This shows that the crown of the hammer is comparatively soft, while the under felt is hard. In such a case one should take a felt picker provided with two long, fine, No. 7 needles, and use these to dig down into the under felt. In this manner the lower layers may be softened without unduly breaking up the crown.

When the upper surface alone is hard, or when both it and the under felt have to be treated, one must use No. 6 needles for the upper surface. Three or four needles can profitably be used in the felt picker, as they do not now have to be forced so far into the felt. When engaged in softening the hammer one should be careful not to dig or gouge up the surface, nor to "pick up" the felt on the top. This sort of process merely

acts on the surface and has neither effectiveness nor permanence. The hammer should be stabbed all round its surface, the needles entering as the spokes of a wheel towards their hub. When it appears upon examination that the hammers are almost uniformly hard throughout they may be softened *en masse*, and the rough voicing then smoothed out by individual tests of each note.

Upon the skill with which the various processes incident to voicing are performed depends oftentimes the whole virtue of a repairing job, according to the judgment of the customer. Indeed, veteran tuners will usually confess that a little judicious voicing will frequently give better satisfaction than the finest and most artistic tuning. This lamentable condition exists largely through the fact that it is easier to perceive differences of tone quality than of pitch. While, of course, one must not thereby take any less care to do one's tuning as perfectly as possible, still this does show that the matter of voicing is exceedingly important, and should command the careful attention of every tuner. Indeed, the tuner who is not an accomplished voicer has not mastered his profession by any means.

CHAPTER VIII.

OUTLINES OF TUNING PRACTICE.

As in all other professions, so in ours, there have grown up certain practices which have been hallowed by time into precedents, and thence into unwritten but well-recognized laws. These chiefly refer to the dealings and conduct of the tuner towards his patrons, the quantity and nature of work included within what is known as a "tuning," and other matters of a cognate form. But equally included within this classification are other matters which may better be referred to the practice of the art as distinguished from its business side. It will be necessary for us to consider both of these divisions in their order.

Taking the latter first, we have to consider such matters of tuning practice as we have not hitherto discussed or to which it has been impossible to devote separate chapters. Among these is the matter of what may be called elementary repairing.

The tuner who has completed a course of work in a factory or wareroom and has there learned a great deal about fine tuning of new and comparatively new pianos, would be greatly mistaken if he were then to imagine that his profession had been mastered. For it is only when one has had a lengthy experience with old and worn-out instruments of every make, style and condition of debility that one can truly call oneself a graduate tuner.

And it is the treatment of small problems of detail, the little extra regulations that must be done, the skillful touch here, the intuitive knowledge of how to cure a jar there, that mark the hand of the master. Nor can this superlative kind of ability be attained without long experience. Yet the hints contained in the following lines may be of great assistance in smoothing the path:

The one cardinal rule to be remembered by him who aspires to success as an outside tuner is this: Very few customers are able to appreciate the subtle refinements of tuning. When they send for the "tuner" they do so because the piano sounds wrong to their ears. Inasmuch as these are generally more or less uncultivated, it follows that what sounds wrong to them is likely to be as much

a matter of regulation as of tuning. In fact, it is to be remembered as an axiom that the term "tuning" means to the average citizen and his wife any and every sort of remedy or repair that a piano can conceivably need.

Now such a misconception on the part of customers is known to exist, and there is not a veteran tuner but will admit not only this lamentable fact, but also the further one that it is entirely hopeless to attempt to educate public opinion on these points. It, therefore, remains for us to observe always the happy medium between too rigid adherence to the letter of our business agreements and too easy acquiescence in the often unreasonable requests of the ignorant or careless.

In short, while we must always expect to be obliged to do a little more than merely tune the average piano in a customer's home, at the same time we should be foolish if we made a practice of doing all that our artistic and mechanical instinct deemed necessary just to satisfy ourselves and without reference to the proportion between work and fees. So that it is well for us to understand from the start about what we ought to make a practice of doing when called upon to "tune" a piano. This can be stated with little trouble, and

a discussion of the matters included will be a part of the next chapter.

As suggested before, we are now in a position to take up for discussion certain aspects of the attitude assumed by the tuner towards his patrons.

First of all, this discussion must take account of the quantity of work which the tuner may reasonably do for a reasonable fee. On the average it is fair to estimate the fee for tuning as two dollars and fifty cents. Taking the whole country together, this average is very close to the truth.

Now, the quantity of work which a tuner can reasonably do depends upon the size of his fee. If that fee be two dollars and one-half, it will be profitable to undertake tuning in so comprehensive a way as to destroy the possibility of complaint from intelligent persons. My own experience has led me to formulate the following method, to which I adhere as consistently as possible:

When I am called to tune a piano for the first time, I invariably begin by examining it quickly, so as to ascertain whether any grave defects exist that may require special treatment, and for the remedying of which an extra fee must be charged. In this category one will include soundboard

splits, sprung and loose soundboard ribs, broken strings, split bridges, broken hammers and other similar matters.

Suppose that there is nothing of this sort requiring treatment. The fee being fixed at \$2.50, the tuner should proceed to blow out the dust and dirt from action strings with a piano-maker's bellows, then tighten up the action screws, and do such regulating as may be absolutely necessary to secure the correct operation of any hammer or hammers. Then the tuning may be done.

When undertaking the actual tuning, note that it will frequently be impossible to make an old piano stand in tune with one operation. In such cases never hesitate to put in extra time at the work, going over the affected parts as often as required. Do not attempt to slight or slur any part of the work.

On the contrary, however, there is no sense whatever in undertaking to raise or depress the pitch of a piano for one fee, since one may thus know in advance that at least three thorough tunings, some days apart, are necessary to do this kind of work so that it will stand well. Even with every precaution, it is usually impossible to guarantee that a much-used piano will stand at a

higher pitch than that to which it has been accustomed, and for which it was designed. When the attempt is to be made to raise the pitch let the instrument be cleaned of the rust that gathers on turning-pin coils, belly-bridge and hitch-pins, and then let the strings be quickly and roughly drawn up a little higher than the desired pitch and then immediately be gone over again with greater care. If the customer will consent, let another tuning be given in three days' time or so and a final one about a week after the second. In this way one is doing everything possible to assure the standing of the piano in tune.

Similar precautions should be taken when one is about to depress the pitch of an instrument.

The tuner needs to possess sometimes no little tact when attempting to make such matters as these clear to the understanding of his customer. He will find it needful to be patient, calm and polite, but also firm, for it is often anything but an easy task to make a customer appreciate either the necessity for, or the cost of a detail in repairing.

Difficulties of this kind can only be explained when one fully appreciates the fact that the aver-

age customer has only the vaguest notions concerning the inner nature of the tuner's work. Attention has already been drawn to this fact, which should at no time be lost sight of.

CHAPTER IX.

SOME INCIDENTAL REMARKS.

We have investigated, in the last eight chapters, the various problems that the piano tuner is obliged to encounter and solve in the course of his daily work. The task has been pleasant, nor has there ever been cause for regret that it was undertaken. There has been every reason to believe that practical piano men would welcome further discussion of the fundamental problems of piano tuning, both in its theoretical aspect and as a matter of daily practice. At the same time it should not be supposed that the discussion just finished has been absolutely exhaustive. For, indeed, this was not to have been expected. The subjects taken up and treated were large in content and unlimited in the scope which they give to discussion and variety of opinion. Indeed, the chief value of such a series as we have just completed is that it affords a basis whereupon the upholders of different schools of opinion, or even the individual free lances, may criticise, destroy

or construct the numberless systems which from time to time one or another practitioner feels called upon to erect.

It is one thing to be certain of one's facts and to know how to put a resume of them on paper. It is quite another thing to assume that one's own knowledge is entirely unimpeachable, or beyond criticism.

One is impelled to the above remarks by the reflection that the publication of systems of practice is necessarily a somewhat delicate undertaking. In an art such as ours, where the very fundamentals are a matter of question, and where the premises upon which conclusions are based are continually being subjected to further analysis and criticism, there is no value in assuming an attitude of oracularity.

It is a most remarkable fact, which would be incredible as applied to almost any other art, that the general run of tuners pay little, if any, attention to critical and analytical work in reference to the science and practice of tuning. And yet it is not to be believed that this attitude is entirely owing to natural indifference or indolence. It would be absurd to suppose that ware-room, outside, and independent tuners, who form

the majority of my readers in this department, and who are conceded to be the pick of the mechanical forces of the industry, are less critical or keen in their attitude toward discussions that cannot but be of benefit to themselves and to the trade. Therefore, one is bound to look for some other answer to the question implied in this present discussion. We want to know why it is that the best tuners and other similar high-class men are so slow to come forward with their ideas. And the only possible answer seems to be that they are too bashful.

It is true that many men imagine that these discussions are academic and of no interest to any save professed scientists. It surely needs little reflection to convince anyone of the utter fallibility of such a view. For is it not obvious that the principal result of attending to and expressing one's opinion concerning matters which deal with the fundamentals of our profession is to give us a wider and broader view of our work, to lead us to devise better ways of attaining to our practical ends, and, in short, to make us better tuners or better piano builders? And does it need any special demonstration to convince any intelligent man that just in proportion as he in-

creases the excellence of his work, so will his financial and social rewards be increased? It is true that with the noble-minded man who loves knowledge for its own sake this sort of an argument will not have much weight. But it is not vitiated by the fact that the conclusion drawn from it is of a material nature. On the contrary, the argument in favor of increasing one's knowledge bears with it a material conclusion merely as an incident to the great general conclusion, namely, that knowledge is power, and that the man who diligently seeks after knowledge shall have his reward. That this reward will be in part of a financial nature no one can doubt who knows anything of the matter, yet the other consequences that flow from this conclusion are far greater and far more important. If I am able to improve my knowledge of things in general by the most infinitesimal fraction each day, I am by that much a stronger man, better able to bear my part in the struggle for existence and better able to mix honorably with my fellow men. Knowledge is power, and power is happiness, strength and prosperity.

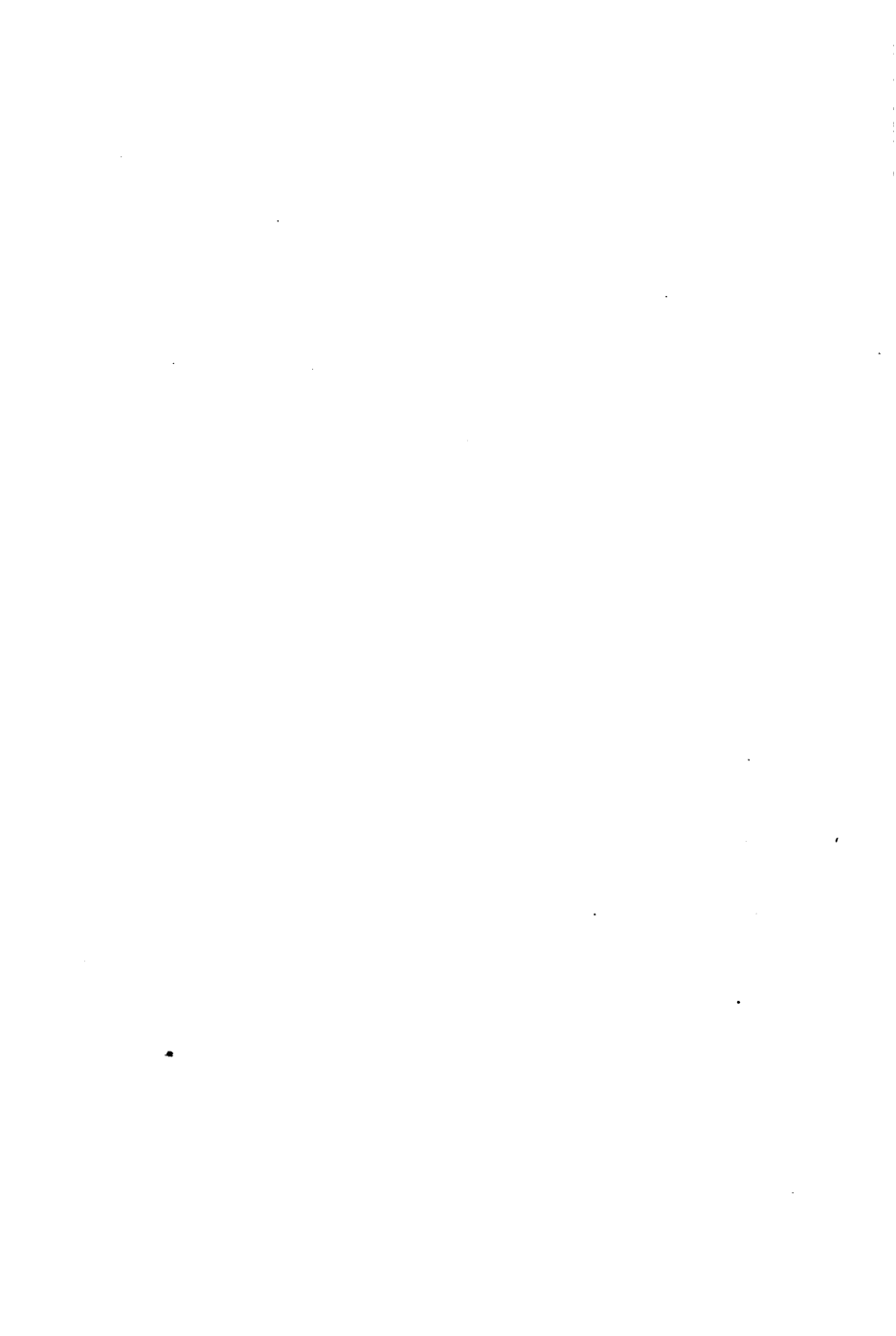
It was the author's destiny to enter the piano trade with neither mechanical experience nor

financial assistance. His equipment consisted solely of an excellent education and a marked leaning toward science and music. Within five years of the day that he first started to learn stringing and action finishing in an obscure shop in New York, he had been able to evolve the systems of piano construction and tuning practice which were afterward elaborated in "Theory and Practice." And yet he had to work as hard as any other apprentice, nor was his work done for the purpose of getting a little extra pocket money; on the contrary, those were days when the pitifully small weekly wage was badly needed.

It is with no boastful feeling that the author speaks of these things. Indeed, his only desire is to show by the example most familiar to him, that a position in the industry and a fund of useful knowledge is at the command of anyone who cares to take the trouble to acquire it. "He who runs may read."

This may appear to be a somewhat remarkable ending to a series of chapters on a technical subject, but in reality it is most appropriate. How can I better emphasize the necessity for acquiring the kind of information that I have been trying to impart in these chapters than by pointing

out the advantages to be derived from study, reflection, and thought on all lines related to our profession!



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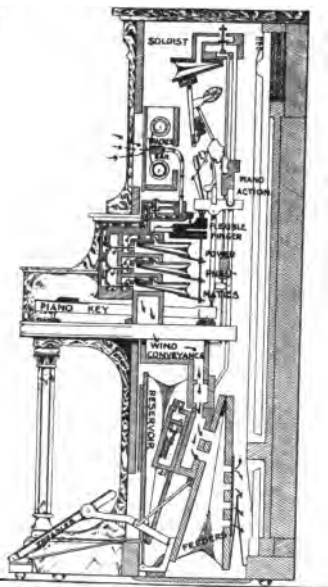
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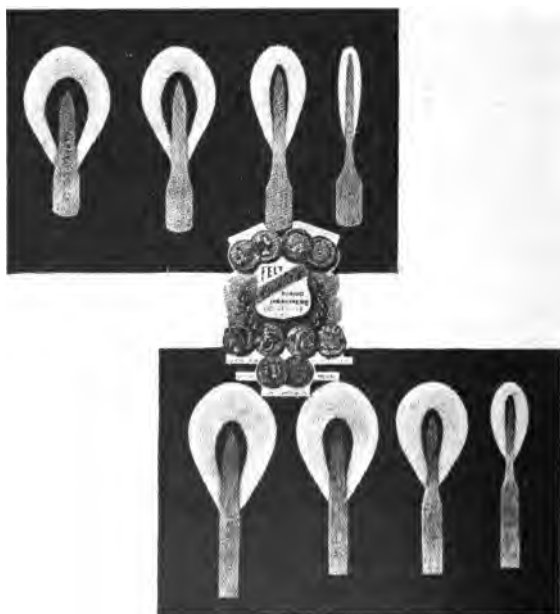
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